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ABSTRACT

The relationship between meaning and vocabulary in four professions--anthropology, linguistics, psychology, and computer science--is examined. Current relational theories within each profession are compared with respect to goals, methodologies, and proposed relations. Certain core relations appear in each discipline, and these are tabulated and discussed. Several additional relations, which seem significant because of their frequency across disciplines or their centrality in an author's work, are described briefly. Underlying models of the lexicon are examined in an effort to address many of the conflicts about relations. The concluding chapter presents a brief summary of the place of relational models in the various disciplines and raises some unanswered questions. (Author/JB)

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LEXICAL-SEMANTIC RELATIONS:

A COMPARATIVE SURVEY

CURRENT INQUIRY INTO LANGUAGE
AND LINGUISTICS 34

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A COMPARATIVE SURVEY

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TO ALL OUR RELATIONS

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INTRODUCTION

Over the past few years semantics has increasingly become a center of attention for several disciplines. Coming from the fields of Anthropology, Linguistics, Psychology, and Computer Science, we have tried to answer different, but related questions about semantics which have arisen in the course of our research:

> How can we make a machine that answers questions?
>
> How does a child learn meanings?
>
> How does a member of a culture acquire and store knowledge about that culture?
>
> What is the internal structure of a concept?
>
> How much of what we know is shared, how much is individual?
>
> Can computers help write better dictionaries?
>
> How does one understand new words?

Any attempt to answer these questions must be based on an underlying semantic model.

There have been three major models of semantic organization. The first viewed meanings as forming fields or domains. An early example of this approach was by Trier

(1934) who examined the semantic domain of lexical items concerned with 'knowledge'. Trier was interested in how a set of terms divided up a semantic domain and how, as one term shifted over time, all the other terms shifted as well. Trier's approach is essentially structural, i.e., a term is defined by its place relative to all other terms in the field. The structural approach to semantic fields or domains became prominent in linguistic anthropology and is particularly useful in examining clearly circumscribed domains like color terms, kinship terms, and systems of personal pronouns. Different types of structures have evolved to portray these fields and others like them.

While some authors concern themselves with the relative positions of lexical items in a domain, others seek to discover what enables a set of lexical items to form a domain in the first place. This second model of semantic organization embraces both componential and feature analyses since questions revolve around what components, features, or properties of lexical items are held in common in order to form a field or domain. Further analyses show not only the common features, but the different features which serve to keep terms within a domain distinct from one another. For example, all birds share the features or properties of being animate but nonhuman, of having feathers and wings. Yet particular birds differ as to size, color, geographical distribution, etc. Most often authors using the feature model conceive of features as binary, but some allow for degrees of a feature. In addition, differences have developed within this approach as to the necessity of a given feature for determining membership in a domain. Some features are considered 'defining' or 'primary' while others are considered 'characteristic' or 'secondary'.

The third model of semantic organization begins with an acceptance of semantic domains as well as the properties which bind items to the domain in general and differentiate items from each other. In other words, this approach views birds as forming a domain whose members are related and differentiated one from another by properties. This third model, however, asks how all these elements are related; it can therefore be called a relational model. The reasons behind the additional emphasis on relations is twofold. First, authors who use a relational semantic model hold that the structural organization, which is implicit in the other models, must be made explicit. Thus, items in a domain may exist as members of a class, as in the case of robin or sparrow forming a class, bird; or they may exist as different kinds of a more general category, e.g. animals, vegetables, things. Or, properties which distinguish items may be modifiers such as winged, feathered, brown, wood; but under the heading of modifiers, many different relationships are obscured. For example, the relationship of blue to car is different from that between car and metal or four-wheeled or vehicular.

Even in such a brief overview of different models many questions arise: for example, the difference between the extension of a term (bird: robins, sparrows, etc.) and its intension (bird: properties); the difference between class membership and class inclusion; relative position of items in a domain and members of a set; the relationship of semantic organizational models to models of memory or more general models of language or cognition. These and other issues will be discussed below and throughout the book.

Approaches using fields and features have already been surveyed in the literature: semantic fields by Ohmann (1953) and semantic features by Hammel and D'Andrade (1965), by Tyler (1969), and by Colby (1966). This book is designed to examine the third approach, that of semantic relations. Relations appear in different contexts as semantic relations, lexical relations, lexical functions, predication relations, text or discourse relations, or as case relations. The variety of terms (and this list is not exhaustive) is representative of the different above-mentioned disciplines, with their attendant diverse goals and methodologies.

Due to the number and diversity of contributors from each field to a theory of semantic relations, an exhaustive exploration would be impossible. We have tried, rather, to look at the work of some representative authors in each field who concentrate most on relations.

Each discipline may influence the approach of an author, but each author uses relations differently. Some authors have more complete and elaborate sets of relations and a more thorough delineation of the significance and scope of each relation. (These are compared in some detail in the text.) In Anthropology we examined the work of Frake, Casagrande and Hale, and Werner; in Linguistics, Fillmore, Chafe, McCawley, and Apresyan, Mel'čuk, and Žolkovsky; in Psychology, Collins and Quillian, Rumelhart, Lindsay, and Norman, Kintsch, and Riegel; in Computer Science, Raphael, Simmons, and Schank. We found that, although the differing goals and methods create different foci and terminologies, still authors from each discipline were often talking about similar relations.

Attending to the relations themselves, we wanted to compare, for example, different uses of 'synonymy' or the extent of variation in terms used to label class-inclusion such as 'ISA', 'taxonomy', 'superordinate', or 'hyponymy'. Therefore, for each relation we initially created a list with definitions, descriptions, and examples of that relation.

Looking at these lists, we found several relations which seemed central either because they appeared in many different theories, though not always with the same label, or because they were crucial for several authors.

From these lists we distilled sets of important relations which are representative of each discipline (Table IV in the text). Our next task was to provide an in-depth study of each of these major relations: taxonomy, modification, synonymy, antonymy, and grading. Information on each relation includes: comparison of uses across disciplines, a description of the formal properties, and a brief introduction to issues and conflicts that seem to surround the relation.

In addition to the detailed examinations of the major relations, we decided to provide a briefer discussion of some other relations: part-whole, cause, space and location, provenience or source, and text relations. This second group of relations was less widely used in the theories we examined, yet the relations seemed to us to be equally important, perhaps equally fundamental.

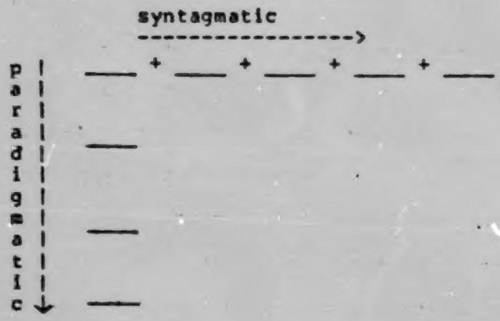
Throughout our work on relations a series of questions and issues surfaced, sometimes in connection with a particular relation but often in conjunction with the form and use of a relational model for semantics. The scope of questions varied: some are of importance to anyone working in lexical semantics; others are relevant to those who would choose a relational model of semantic organization; still others are pertinent to the use of a particular relation or set of relations.

We have handled these questions in three ways. As indicated above, we have attempted to raise issues surrounding a particular relation or the interface between relations at the appropriate point in the text. Secondly, we have devoted a separate chapter to the major issue of collocation and derivation. We had not anticipated that this issue was to be so important, but in working with the relations we found that it surfaced frequently as a problem for all disciplines and all approaches. We felt therefore that it deserved separate treatment. Lastly, we have placed in this introductory chapter those questions or issues which arise out of general theoretical themes as well as information of a background nature which might help the reader better understand lexical-semantic relations. It is to these themes that we now turn.

PARADIGMATIC AND SYNTAGMATIC RELATIONS

Paradigmatic and syntagmatic relations mark dual axes

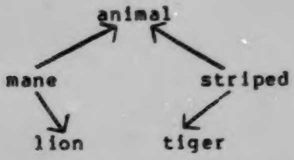
(Saussure 1959[1916]) or duality of patterning (Hockett 1966) of natural (i.e. human) languages. The paradigmatic axis is vertical (see illustration below) and is defined as substitution sets of the same word class which can fill slots in a frame along the alternate axis, the syntagmatic. The syntagmatic is the horizontal axis of language, a consequence of the linearity and temporal sequencing constraints of language (Lyons 1977:240).



In the very loosest sense, this schema translates into: (1) syntagmatic = syntax, syntactics, or phonotactics (on the level of phonology) and (2) paradigmatic = lexicon (inventories, lists of words or sounds).

Since the lexicon is not a simple list, the dichotomy between the two axes becomes problematic. For those who see the lexicon as organized into fields (e.g. Trier, Porzig), the notion of paradigm is adequate. For those who see the lexicon as sets of features (Katz and others), paradigm may not be ideal, but it is still sufficient. (The use of the term paradigm here comes from Linguistics and should not be confused with its use in Anthropology or Philosophy of Science, e.g. Kuhn 1962.) For relational semanticists who want to enumerate not only the members of a lexical field (like field theorists) and the properties which include and separate them (like feature theorists), but also the relationships among all these, paradigmatic begins to merge into syntagmatic.

For example, the following diagram, can be described as a paradigm of the animal field and the features which define its members and the relations (Taxonomy and Modification) obtaining between them:



But such paradigmatic relationships can be expressed syntagmatically:

A lion is an animal with a mane.

A tiger is an animal with stripes.

Lions and tigers are animals.

Two kinds of animals are lions and tigers.

The problem is to differentiate between these syntagmatic examples and others such as:

The lion is loose in the city.

There's a tiger in your tank / in your kitchen.

As in these examples we seem to receive paradigmatic information typically in generic (always true) sentences, while syntagmatic relationships come to us in occasional sentences. A generic or standing sentence contains a piece of permanent information about the world, such as 'Food is edible'. An occasional sentence contains information about a particular context, while generic information is not usually bound by any narrow context. The distinction between standing and occasional sentences is therefore a means of characterizing the way in which we make generalizations about the world. Occasional sentences are more truly syntagmatic in the original sense. We can also use notions of type and token to mark a similar difference between a general concept, such as the phonological representation /dɔg/, and a particular instance, like the phonetic record [dɔg]. (But see II.2.e.i.)

A major difference between traditional Transformational Generative Grammarians and Generative Semanticists concerns the distinction between paradigmatic and syntagmatic. The traditionalists in Transformational Grammar are mostly concerned with syntagmatic or syntactic relationships and utilize a paradigmatic lexicon. Generative Semanticists, on the other hand, view both lexical items and sentences as organized by similar syntagmatic means (McCawley 1970, following Weinreich 1966), which are not relations but 'predicates' and 'arguments' as in formal logic. Nevertheless, there still seems to be room in the Generative

Semantics view for some aspects of a paradigmatic lexicon of the traditionalists' sort (McCawley 1979).

In word association and definitional tasks, these two axes of language are invoked to classify response-types. Paradigmatic responses are those which could substitute for the stimulus or cue word, e.g. mother - father, orange - fruit. Syntagmatic responses are those which may follow or precede the stimulus/cue word, e.g. mother - love, orange - eat, bicycle - ride.

Some theorists have followed this interpretation by defining syntagmatic as that which closely follows, i.e. the immediate context. For example, although he is largely interested in paradigmatic relations, Riegel has a relation called preceding-succeeding. And many of the relations of Apresyan, Mel'čuk, and Žolkovsky which we have labeled collocational could be seen as syntagmatic in this sense. In this book we use the term collocation in a wider sense, as the result of the occurrence of two or more lexical items contiguously or near-contiguously in a text. This is closer to the view held by Halliday and Hasan (1976).

As a general rule, those interested in surface forms or syntax will begin with syntagmatic relations and find the paradigmatic relations most problematic (see Peterson 1973).

Those who begin with underlying semantic (and therefore paradigmatic) models must face the problem of input and output which is necessarily linear and syntagmatic.

PROCEDURAL SEMANTICS

Must one necessarily separate input or output from underlying semantic models? Among authors using relational semantics, Werner alone uses the same three relations (M, T, Q) for all aspects of language. An alternative advocated by the psychologists Miller and Johnson-Laird is a 'procedural semantics in which sentences are decomposed into a variety of procedures or operations that speakers and listeners can perform' (1976:123; see also Miller 1974). The term 'procedural' has its roots in Computer Science. The first natural language processing system to express meanings in terms of procedures was BASEBALL (Green et al. 1961). In BASEBALL the meaning of a word was a subroutine. The meaning of the verb lose, in 'Did Chicago lose to Boston on May third?' was subroutine 10. This subroutine placed the attribute modifiers WINNING and LOSING on the appropriate team descriptors in the form recognized by the retrieval routines. The model of meaning as a procedure in BASEBALL was only a naive beginning, but it had far-reaching consequences for information retrieval.

The procedural view of semantics has been most completely embodied in Winograd's robot SHRDLU as described in his dissertation, Procedures as Representations of Data (1971). In Winograd's model the meaning of 'red block' is a procedure for deciding whether a particular object in the toy world is a red block or not. The natural language models of Schank (1973, 1975), Charniak (1972), and Wilks (1973,1975) can also be described in terms of procedural semantics.

Miller and Johnson-Laird recapitulate their position this way (1976:702):

> - The meaning of a word can tell you what is, and what is not, an entity that can be labeled with that word
> - It incorporates basic semantic operators concerning space, time, cause, and intention.
> - The meaning can tell you the function or purpose of the entity that the word labels.
> - The meaning can lead you to all you know about an entity.
> - The meaning can tell you about relations between what the word labels and what other words label.
> - The meaning of a word can tell you about what other sorts of words can occur with it in sentences. It can place syntactic and semantic constraints on other words.
> - The meaning of words must be compatible with the meanings of sentences. Procedures for constructing sentences and interpreting them must dovetail with procedures for representing the meanings of words.

Procedural semantics is an attempt to describe mental processes. As such it is viewed as heretical by some psychological theorists who take the position that only behavior is describable. This conflict has been called the behaviorism and mentalism controversy.

BEHAVIORISM/MENTALISM

One long-standing controversy has revolved around the nature of the information a model can claim to describe. Is it to be observable utterances or the structure of language in the mind? Behaviorists have held that the goal of a linguistic model is to accurately describe observable language behavior with as little reference to unobservable instincts or processes as possible. They emphasize learning over innate abilities and are very hesitant to describe mental processes, other than complex stimulus-response patterns.

Mentalists, on the other hand, maintain that language is an innate ability and that there is a complex system of rules (called a grammar) in the head of speakers that make it possible for them to speak and understand utterances they have never heard before. They often place little reliance on observable language behavior because they feel that it is full of errors and is affected by nonlinguistic factors such as stress, fatigue, time pressures, and hearing loss, which may confound explanations of the optimum ability of native speakers. Instead mentalists rely heavily on native speaker intuitions about language, using these intuitions and their own observations to develop models which characterize what happens in the minds of native speakers.

The differences between the behaviorist and mentalist views can be exemplified by examining their approaches to language learning. According to behaviorists, language development is environmentally produced and does not differ significantly from other types of learning. As a consequence, behaviorist models of language development, such as those found in some psychological theories, are stimulus-response models, which differ little from models used to account for other types of behavior.

Mentalist models, on the other hand, reflect the belief that language learning in humans is innate and distinct from other types of human learning. They attempt to characterize the language acquisition capacity of children and are interested in the linguistic maturation process. Like mentalist models of adult language, models of language development often contain a complex system of rules.

Models containing semantic relations are classified among the mentalist models. However, the researchers we have included in this book differ greatly in their willingness to assert that their models actually represent the mental processes of native speakers.

PSYCHOLOGICAL REALITY

In their attempt to characterize the mental processes which underlie language, mentalists often see psychological reality as a crucial test of the adequacy of their models. Evidence for psychological reality may come from native speaker intuitions or from informant behavior on a variety of tasks. The viability of claims about psychological reality is, however, thrown into question by the fact that models of vastly differing structure may account for the same language phenomena.

Behaviorists are not bothered by questions of psychological reality since their models claim only to describe observable utterances and make no claims about the representation of language in the human mind. They judge a model on the basis of its success or failure at the task of describing language behavior.

COMPETENCE AND PERFORMANCE

In the field of linguistics there is often a clearly stated distinction between the speaker's knowledge of language (langue), which may or may not be conscious, and the use of language in concrete situations (parole). This distinction was first formally proposed by Saussure (1959[1916]) at the beginning of the twentieth century. Saussure's principal concern was with the explication of langue. The distinction between langue and parole achieved considerable popularity with the advent of transformational grammar when Chomsky (1965) reformulated the distinction and called it competence and performance. Transformationalists agree with Saussure's emphasis on mental knowledge over behavior. They feel that the study of language behavior (performance) can only be properly done after we achieve a thorough understanding of the language structures and processes of competence. Performance is considered to be a complex behavior or surface phenomenon which is governed by linguistic and nonlinguistic factors, including memory limitations, emotions, confusions, and errors, as well as by competence. Competence is the linguistic knowledge which is said to underlie performance and which would be equivalent to performance if the speaker were an ideal speaker-hearer free from nonlinguistic interference. Recently, the dichotomy between competence and performance has been called into question. Some critics claim that there should be no distinction because the use of linguistic knowledge must be a part of competence. Others maintain that if a speaker knows how to use linguistic knowledge, that itself is a form of competence. One issue is whether the difference between competence and performance is really a difference involving constraints on memory function - that is, either performance may be viewed as competence clouded by memory limitations, or competence and performance involve different kinds of memory functioning.

MEMORY

Traditionally, researchers have posited two kinds of memory: short-term memory and long-term memory. As the modifiers, short and long, are used, these types are differentiated by the amount of information each can hold, the amount of time for which information can be kept without loss, and the amount of reorganization possible. Short-term memory is considered shallow, fleeting, and without capacity for reorganization, yet able to grow and change. It is sometimes compared to a filter which can hold 7±2 or 5±2 (Miller 1956; Mandler 1970) bits of information for a very short period of time after which it may be passed into long-term memory or be lost. Because of this initial filtering function, in which it serves as a gateway to long-term memory, short-term memory is sometimes referred to as primary memory (vs. secondary) and its role in focusing attention is stressed (Norman 1976).

Since information apparently goes first into short-term memory, this primary memory is often seen as specific to the particular sense modality that is the source of the information. Psychologists and others who take an information processing point of view speak of visual short-term memory as opposed to auditory or haptic short-term memory. Short-term memory does not contain large stores of information but, rather, allows access to the stores which reside in long-term memory.

Long-term or secondary memory has virtually an unlimited capacity for information which continues to collect throughout a lifetime (barring cerebral damage or disease) and which is continually reorganized on the basis of incoming information. In turn, long-term memory enables change in short-term memory by enhancing its capacities. The information in long-term memory, which is essentially one's world knowledge, is not considered modality-specific but is, rather, thought to be highly influenced by that aspect of the language system called 'semantics'. For this reason, long-term memory is often referred to as semantic memory (also: 'associative memory' by Anderson and Bower 1973). In this view syntax is an aspect of the short-term memory filtering system in that it holds or 'chunks' (Miller 1956) information so that meanings can be extracted and passed along to long-term memory for interpretation and storage. For syntactic or semantic theorists who view both syntax and semantics organized as some form of predicate calculus, there would not be the sharp distinction between types of memory and levels of language. In fact, they might argue that similarity of structure enhances transfer of information between parts of memory.

Information processing theorists who must account for inter-sensory processes and integration as well as intra-sensory processing will sometimes hypothesize levels of processes (e.g. Craik and Lockhart 1972). In addition, some theorists posit an intermediate stage in memory between short-term and long-term (e.g. Werner 1974). Ever since Tulving (1972) first proposed the concept of another type of memory, one which would complement semantic memory, and called it episodic memory, there have been divided opinions on the status of this new category. Some have deemed the new type unnecessary: Norman (1976:189) has suggested that all memory may really be semantic, while Schank (1975c:255) claims that all memory is really episodic. What is at issue is not whether there are two compartments or components to long-term memory, this being merely a problem for modeling or building of visual representations of memory, but rather whether there are indeed two ways to process information.

The major impetus to a two-component long-term memory theory comes from research in cognitive and linguistic development. Responses by children to word associations, classification, concept-formation, definitions, and other tasks indicate that young children's memories seem to be largely episodic in character and that they gradually become increasingly semantic in nature as the child gets older and has more experiences. (Petrey 1977; Nelson and Brown 1978; see Miller and Johnson-Laird 1976:467-8).

On the one hand, material in semantic memory, having arrived there via the short-term memory filter, is decomposed information. Its state is altered from input so that there is a difference between input-form and storage-form. This information is hierarchically organized by classes and common properties, and is related by sets of powerful semantic relations, such as taxonomy, synonymy, and antonymy, whose deductive powers (e.g. symmetry, transitivity, reflexivity) allow or disallow inferential leaps around conceptual space.

On the other hand, material in episodic memory is closer to actual experience, including language as experienced (e.g. memory traces for actual sentences and phrases). The difference between input-form and storage-form is minimally distant. Information in episodic memory seems to be prior to and preparatory for the later decomposition of semantic memory. Episodic memory information is embedded in the context of experience. Tulving has characterized it as tied to temporal, spatial and autobiographical contexts, as opposed to the abstract, general semantic memory, which is true for all times and places. Actual sentences uttered as part of a context are remembered in episodic memory while the abstract semantic information that is encoded in the sentences is retained in semantic memory (cf. occasional vs. generic or standing sentences and type-token differences). Schank (1975) goes so far as to insist that all information is stored in memory in contextual frames since all information occurs in common sequences (scripts) which are linked together in causal chains: there are no categories 'tool' or 'food', but only occurrences in episodes where these terms have functioned. Upon recall, the whole context is recalled. While there are several hypotheses concerning the structure of semantic memory (Smith, Shoben, and Rips 1974; Rumelhart, Lindsay, and Norman 1972; Anderson and Bower 1973), few theorists have hypothesized what episodic memory might contain in order for it to function as theory claims it must.

Some theorists, e.g. Miller and Johnson-Laird, view the episodic - semantic difference as a question, not of input and storage, but rather of retrieval strategy. They first expand a theory of different fields of memory, in which episodic and semantic would be two such fields, others being geographic, temporal, person fields, etc. (1976:146-152), and then show the inefficiency of such an approach. It is not clear that Tulving really meant this distinction to be a 'field' distinction or whether it was meant to apply to retrieval, input, or storage. Certainly, as these and other authors have pointed out, certain requests for information, such as 'What did you eat for breakfast?', entail episodic information and instigate an episodic search; while other requests, like 'What kinds of birds are there?' or 'Is a penguin a bird?', entail semantic information and instigate a semantic search. While all three are questions, they differ in form as well as content. Are we, then, dealing with questions of input, of storage, of search and retrieval strategy, or of statement form?

In an effort to discover cultural differences in memory as an aspect of cognitive functioning (e.g. Cole and Scribner 1974), recent cross-cultural studies have hypothesized a distinction between universal structural processes of memory (such as size of short term stage and rate of transfer between short and long term components) and culture-specific control processes (such as rehearsal strategies, variability in stimuli encoding, search procedures) (Laboratory of Comparative Human Cognition 1979:162).

These questions raise a basic issue concerning memory research. How much should one build into one's model as absolute structure and how much should one allow for processes or strategies that operate on that structure? One type of process or strategy which has received attention is inference.

INFERENCE

Inference can be defined most simply as the process of going beyond the information given in a text or discourse, the process of drawing new conclusions from previous knowledge. In semantics the previous knowledge, the information given, is semantic structure. For the theorists we are examining, this structure is a large interconnected network of related information. In such models inference is possible either (1) as a consequence of the structure itself, or (2) by the application of rules which are external to the structure but operate on it.

In the first case, inherent aspects of semantic structure allow inference. For example, a model may embed the transitivity of the taxonomy relation into the structure of memory. It is this transitivity which allows one to infer that dogs are vertebrates when we know that dogs are mammals and mammals are vertebrates. So inferences of this type are a consequence of the structure of the model (Werner 1972a).

In the second case, external rules are posited which allow for the processing of information in the structure. Modern presentations of formal logic usually provide both a structure for information, including a grammar for formulas, and a separate set of rules for manipulating the information. In his development of the first-order predicate calculus Church (1956) gives a collection of formation rules for well-formed formulas and then two rules of inference which operate on these formulas: the Rule of Modus Ponens and the Rule of Generalization.

Whether inference potential is hypothesized as inherent or external to the structure depends, partly at least, on considerations of the history and philosophy of a particular discipline. Psychology has traditionally used extrinsic models to represent processing strategies, to explain the learning of new information, developmental restructuring of old information, and the utilization of information in goal-directed tasks like problem-solving. (See Rumelhart and Abrahamson 1973, on analogy; Newell and Simon 1972, on problem solving; Kintsch 1972; Rumelhart, Lindsay, and Norman 1972.) The dominating principle of parsimony of information has led linguists to use redundancy rules for inference making. Recently some linguists have incorporated symbolic logic into linguistics (for example, see McCawley forthcoming; Lakoff 1970). Anthropologists are making an effort to discover whether rules of inference are part of the structure of a particular culture or whether they are separate from cultural-specific knowledge, even universal (Hamill 1974; Loflin, Guyette, and Marlin 1973). Computer scientists have used both kinds of models of inference. On the one hand, experiments in theorem proving (Robinson 1965; Henschen, Overbeek, and Wos 1974) are based on logical systems with external rules of inference. On the other hand, Winograd's robot SHRDLU uses rules of inference embodied in the same kind of procedures as all his other knowledge.

While some cognitive tasks require use of inference, others do not. Some studies refer to recall memory as opposed to recognition or reconstructive memory. These terms do not really refer to types of memories but rather to kinds of tasks (either tests or experiments) which require varying kinds of encoding in and retrieval from memory. Depending upon the particular task, the kind of memory involved might be any of those mentioned above. For example, if you gave someone a list of words and asked for immediate recall, you might be evaluating short-term memory; if you asked for recall two months from now, you might be evaluating long-term memory; if you did not ask for recall but rather presented two alternate lists and asked the person to choose which he has previously learned, the task would become a recognition task. Task demands are not the same as memory types but, obviously, interact with them; research shows that subjects remember differently for different tasks.

What is the content of memory? What is the mental image of a term? Is it a list of things we have heard called by that name (extension), or is it a collection of attributes (intension)?

INTENSION/EXTENSION

The debate about whether to consider the extension or intension of a term as primary is reminiscent of the dichotomy between the behaviorist and the mentalist approaches to model building. By extension we refer to all the things which a term names. Thus, the extension of the term fruit includes individual apples, as well as cherries and guavas. The term apple itself encompasses Jonathans, Granny Smiths, and Red Delicious apples among others. A strict extensional approach is limited to the forming of sets of things and makes little attempt to posit conceptual underpinnings or otherwise account for the nature of distribution of the sets of items.

The intension of a term refers to the set of attributes which characterize that term and makes no reference to objects it names. The intension of fruit, for example, includes 'part of a plant', 'seed bearing', and 'usually edible'.

Few researchers adopt strict extensional or intensional approaches. They typically select combined approaches where one or the other is held to be prime. Often the preference for an extensionally prime or intensionally prime approach varies with the field of specialization. Computer scientists, for example, have tended to organize material primarily on the basis of extension while linguists have often preferred intensionally focused models.

As in the behaviorist/mentalist debate, the disagreement between extensionalists and intensionalists revolves around a corresponding disagreement as to whether a model of language behavior can claim to represent the human mind. Those who adopt extensionally prime approaches try to characterize human behavior without claiming psychological reality for their models, whereas intensionalists may make explicit claims about the correspondence between their models and human language competence or memory.

One major problem is that most researchers do not clearly distinguish between intension and extension in their models. This creates confusion between the items which are considered to be members of a set and the attributes which they share as set members. Furthermore, the attributes themselves are probably members of other sets. If, in the set labeled bird, we do not distinguish set members (e.g. robin, eagle, chicken) from attributes (e.g. has wings, has feathers), we may have difficulty formally distinguishing the set of birds from another set which might be labelled body parts, for which wings and feathers are set members but which has an entirely different set of attributes.

FUZZY SETS

One area which some intensionally based models have begun looking at is typicality of set membership. Fuzzy set membership is an extension phenomenon which points to the fact that certain members of a set can be judged more typical examples of the set than other members. In the set labeled bird, for example, a robin is often judged more birdlike than an eagle and both are judged to be more typical than a chicken. Since Zadeh (1965) first proposed the notion of graded set membership based on typicality, considerable research has been done in the fields of Psychology (Rosch 1973; Rosch et al. 1975, 1978); Anthropology (Kay and McDaniel 1978); Linguistics (Lakoff 1972a; Markowitz 1977; Newport and Bellugi 1978); and Computer Science (Zadeh 1975; Tanaka and Mizumoto 1975). Intensionalists such as Rosch have attempted to provide psychological constructs such as family resemblance and category prototypes to account for typicality rankings. Rosch and others claim that there are certain critical or prototypical attributes which tend to be shared by more typical set members, but that there are very few attributes which are shared by all members of a set. Birds, for example, which share the attribute of flight are more typical than those which cannot fly.

Opponents of fuzzy set theory disagree with the notions of relative typicality or the psychological prototype. They argue that effects of frequency of occurrence are mistaken for typicality. This position is not supported by experimental evidence (Markowitz 1977; Rosch et al. 1976), which reveals poor correspondence between frequency of occurrence and typicality rankings.

Initially extension was defined as a catalogue of things which a term names. Some researchers feel that there may also be items which are conceptually distinct from other sets of things, but which are nevertheless unnamed. These unnamed items are called unmarked taxa, and the sets they belong to are referred to as covert nodes.

COVERT NODES OR UNMARKED TAXA

Evidence which is used to support the existence of unmarked taxa often comes from componential analyses and/or from categorization tasks. In a sorting task, for example, informants may respond 'X and Y are both of the same kind, but I don't know what that is' or 'I don't have a name for it'. In such tasks a variety of groupings may appear which seem to generate multiple categories not all of which are explicitly elicitable.

Opponents of the existence of covert nodes claim that unmarked taxa are possible at any intersection of attributes and would therefore be potentially infinite, and that the grouping and regrouping of taxa is a by-product of the sorting and categorization tasks. Therefore, evidence for the existence of covert categories which is based on such tasks is not empirically valid. Furthermore, they claim that any group of taxa which is culturally or psychologically significant would also be permanent and therefore named. They conclude that there is a one-to-one mapping of concepts to labels and direct their energies toward explanations of semantic structure or competence.

Proponents of covert nodes and unmarked taxa are unwilling to dismiss the already elicited evidence of covert nodes and concern themselves with the use of cultural/linguistic knowledge as a means of forming hypotheses and generalizations about competence. They tend to see a greater distance between concepts and labels and are willing to address themselves to understanding the processes by which concepts and labels become linked.

SEMANTIC PRIMES

Semantic primes are still another focus of controversy between contending semantic theories. Each theory defines a different set of semantic primes as primitive elements of that theory, as building blocks from which semantic representations are constructed.

The first question is what is the nature of semantic primes, themselves? What do the elements of semantic representations look like? What are the semantic markers? What hangs from the nodes of the trees? What nestles inside the parentheses of the logical formulas?

Semantic primes are the center of a serious philosophical dispute. Some theorists disagree about whether or not they should posit semantic primitives. Researchers who do include them in their models disagree as to whether the primitives they posit may be selected arbitrarily as opposed to requiring real-world existence or psychological reality for the primitives. One basic disagreement centers around whether primes are to be considered as having some existence in nature like chemical elements, for example, or as purely theoretical constructs, chosen for convenience, as a mathematician may choose a convenient basis for a vector space.

The clearest statement of the position that semantic primes have a real existence is Zwicky's 'Substance Theory of Semantic Primes':

> Every semantic prime is realizable as a lexical unit (root, inflection, or derivational affix) in some natural language (1973:473).

He explains further: 'Every semantic prime is a real substance (a root, inflection, or derivational affix), not merely a principle manifested by real substances'. He compares this theory to Boyle's requirement, in the Sceptical Chymist of 1661, that chemical elements be isolable substances and not abstract principles. It is important to note that when Zwicky talks about real substances he means substances that really occur in language. He does not claim that they have some real existence in a Platonic land of images. Nor does he mean that the prime and the English word are the same thing. All words in everyday use acquire diluted meanings and connotations; the semantic prime has, as far as possible, a single isolable sense. The English word and may indicate time or causal relationships, but one meaning is that of the semantic prime AND, which behaves like the logical operator.

Katz (1966) definitely disallows the Substance Theory, arguing instead that semantic elements in a model are constructs of that model and have no independent existence.

Somewhere between Katz's position and Zwicky's is Lakoff (1970). Since he is concerned primarily with verbs, he calls the semantic primes he is working with 'atomic predicates'. Lakoff uses examples of their explanatory power to argue for the existence of atomic predicates in the logical structure of natural language. For example, he claims that only the decomposition of *prefer* as *like more than* explains the stranded *to* in the sentence, 'What does Sam prefer bagels to?'

Lakoff's (1972b) position on whether the atomic predicates he hypothesizes actually exist in the logical forms of sentences of natural language has been cited by Zwicky (1973:476): 'It is required, at the very least, that such predicates exist elsewhere. For example, there might be a number of other verbs which can be decomposed in terms of one or another of these predicates.' Fodor's (1975) *Language of Thought* also makes a strong case for the reality of semantic primes.

The most complete system of semantic primes has been developed for Russian by Žolkovsky and Mel'čuk (1970). This system, which they call the depth lexis of Basic Russian, consists of lexical functions and independent lexical items. The lexical functions express relationships between words in the lexicon, for example, hot = Anti(cold). The function S_1 relates verbs and their typical subjects: conqueror = S_1(conquest). Entire families of words, then, can be expressed by one lexical item and all its lexical functions. Sometimes there are several possible candidates for representative of a given family; one is chosen arbitrarily. This one is then specifically restricted to a given sense.

Another dilemma about semantic primes is whether they are language specific or language universal. Lamb (1962) claims language universality for his sememes as Schank (1975a) does for the fourteen primitive ACT's in terms of which he expresses the meaning of every verb he encounters. The question of whether semantic primes are universal or whether they are culturally determined and differ from culture to culture is argued again for every proposed set of primes.

Another point of controversy closely related to the question of semantic primes is the problem of circularity of definition.

CIRCULARITY

Circularity is a particularly heated topic among dictionary-makers and dictionary-users, whether they view themselves as anthropologists, linguists, or computer scientists. This question most often arises when someone consults a monolingual dictionary. You look up word A and find it defined in terms of word B. You look up B and its definition uses word C. Then you look up C and find it defined as a kind of A.

Is this kind of circularity inherent in the nature of dictionaries or can it be avoided? Apresyan, Mel'čuk, and Žolkovsky list as the first requirement for a dictionary that definitions should not be circular (1970:4). They claim that words should be defined in terms of more elementary words until, after possibly a number of stages, all definitions are reduced to a small number of indefinable units of meaning. These units of meaning are then represented by pictures, they say. There are two problems here. First, the combinatorial difficulties involved in checking such a dictionary for circularity are immense even in the 2000 entries which they envision. Second, is it really possible to describe all these indefinable units of meaning in terms of pictures? Later in the paper it is indicated that one of these units is cause. What would a picture of cause look like?

This brings us back to issues relating to intension/extension and typicality. For each picturable term, which picture is the most representative? What attributes must be included in the picture? Rosch, for example, would posit a pictorial prototype consisting of the most important attributes. But is one picture sufficient to characterize a term? Avoiding circularity is not a trivial problem.

Winograd , among others, is convinced that circularity is inherent in the nature of language. He disagrees with Apresyan on both practical and theoretical grounds. Circularity cannot be eliminated, he claims, for it is inherent in the way people think and use language.

> Language is a process of communication between people and is inextricably meshed in the knowledge that those people have about the world. That knowledge is not a neat collection of definitions and axioms, complete, concise, and consistent. Rather it is a collection of concepts designed to manipulate ideas. It is in fact incomplete, highly redundant, and often inconsistent. There is no self-contained set of 'primitives' from which everything else can be defined. Definitions are circular, with the meaning of each concept depending on the other concepts. (1971:210)

The issues of intension/extension, fuzzy sets, covert nodes and unmarked taxa, semantic primes, and circularity all involve the underlying model of the lexicon.

THE LEXICON

The lexicon is the focus of controversy along many different dimensions. Its relative importance is open to serious question. Many Soviet linguists claim that the language _is_ the lexicon, the inventory of its words and the ways of combining them, and that the grammar is primarily a means of expressing generalities arising from the lexicon, a convenience for decreasing its bulk. The widespread view in American linguistics is precisely the opposite, that the function of the lexicon is to support the grammar and to reduce the length of the lists of exceptions to the rules.

The organization of the lexicon, its basic structure, is also in question. Is it a list, a grid, or a network? The smaller commercial dictionaries are basically in list form with few cross-references between entries. Anthropologists who have undertaken componential analyses of kinship terms or other specialized vocabularies view the lexicon as a multi-dimensional grid. Still another view is preferred by those who see the lexicon as a complex network structure. Some have suggested that the lexicon can be visualized as a dictionary with a huge single page containing all lexical items and their interconnections. Each item would be the center of a large star with arcs radiating out in all directions, connecting it to other nodes (Bierman 1964). Others envision a still more complex network in which the arcs connecting the nodes are labeled by relation names.

The quantity and kind of information needed in a lexical entry are also the subject of arguments. In his Aspects of the Theory of Syntax Chomsky gives only a brief description of a lexical entry for his model. Each entry is a complex symbol consisting of a phonetic representation, given in terms of phonetic features, and a list of syntactic feature values. As examples he gives (1965:85):

(sincerity, [+N,-Count, +Abstract])

(boy, [+N,+Count,+Common,+Animate,+Human])

(may, [+M])

For further examples, see Chomsky 1970. Katz (1966) gives a more detailed model of lexical entries in a transformational generative grammar. Each different sense of the word is described by a different lexical reading. Each reading consists of a set of semantic markers and a complex symbol called a selection restriction, which is used to prevent anomalous combinations. He gives four readings for the word bachelor:

(i) (Physical Object) (Living) (Human) (Male) (Adult) (Never Married); <SR>.
(ii) (Physical Object) (Living) (Human) (Young) (Knight) (Serving under the standard of another); <SR>.
(iii) (Physical Object) (Living) (Human) (Having the

academic degree for the
completion of the first four
years of college); <SR>.
(iv) (Physical Object) (Living) (Animal) (Male) (Seal)
(Without a mate at breeding
time); <SR>. (1966:298)
(1966:298)

A word like bachelor with four lexical readings is four ways semantically ambiguous, the disambiguation being accomplished by a system of so-called projection rules.

In contrast with this approach Generative Semanticists include a type of listing in their examples of the lexicon which uses underlying predicates such as CAUSE and BECOME which are mapped onto lexical items via a system of syntactic rules. The degree to which the lexicon is independent of syntax depends upon one's model of language. In some models the lexicon supplies the actual content words for a more abstractly coded syntactic component while in others the demarcation between syntactic rules and lexical items is less distinct and more complex.

Authors also vary on the issue of whether the lexicon is a purely abstract linguistic construct or if it also has psychological reality, bearing on categorization, concept formation, and memory. This is related to the question of whether a conceptual network contains conceptual or semantic nodes without lexical labels. Along with the question of the nature of nodes comes that of the nature of the relations which link concepts to labels.

LEXICAL-SEMANTIC RELATIONS

The term lexical-semantic relations means many things to many people. We do not define the term explicitly anywhere in this text; our choice of literature to survey, however, obviously reflects some intuitive notion on our part about what the term encompasses at least within each field. Some authors prefer 'semantic' to 'lexical', or 'semantic' to 'conceptual' or 'syntactic' to 'semantic' (as in the syntactic features of interpretive transformational generative grammar) or vice versa. In general one could argue that 'syntactic' refers to grammatical relations, 'lexical' to actual vocabulary items, and 'semantic' to conceptual categories in memory. This is not always the case, however, and understandably so: lexical items obviously refer to concepts and are stored in memory; semantic categories are expressible in actual verbal items; what some languages put into a lexical item another language may express syntactically; and so forth. Consequently, some writers have begun to set out a preliminary set of definitions in which to locate their particular appproach or to provide an inclusive model with levels on which to locate these terms and show their interrelationships. Often, however, this is not the case and the choice of 'lexical' or 'semantic' by an author may or may not presuppose an implicit assumption of any such model. It is for this reason we have used 'Lexical-Semantic' in the title of our work. Since we come from different backgrounds, we have looked at Lexical-Semantic relations from several different viewpoints.

THE PLAN OF THE BOOK

In Chapter I we compare current relational theories within each discipline, examining the goals, methodologies, and proposed relations.

In comparing sets of proposed relations, we found certain core relations which appeared in each discipline. Each of these major relations is examined in Chapter II from the perspectives of the various disciplines, with a brief discussion of some controversial issues, formal properties, and its connections with other relations.

After the major relations were tabulated, several additional relations remained which, though not major, seemed significant either because of their frequency across disciplines or their centrality in an author's work. These are described briefly in Chapter III.

Many of the conflicts about relations seemed to be based on differences in underlying models of the lexicon. We examine some of these models in more detail in Chapter IV.

Chapter V presents a brief summary of the place of relational models in the various disciplines and raises some unanswered questions.

CHAPTER 1

SOME KEY RELATIONAL THEORIES: A BRIEF DESCRIPTION

In this chapter we present some major relational theories which have been developed in Anthropology, Linguistics, Psychology, and Computer Science. In order to place these theories in proper persepective we have included a brief history of the use of relations for each discipline. We then examine in detail the work of several scholars who have made significant contributions to the understanding of Lexical-Semantic Relations.

1 SOME RELATIONAL MODELS IN ANTHROPOLOGY

Relational models are relatively recent in Anthropology. Prominent among them has been folk taxonomy, which centers on a single relation: taxonomy or class inclusion. Although work on folk taxonomy itself is less than twenty years old, Tyler argues that this notion is 'foreshadowed already in the writings of Mauss, Boas and Evans-Pritchard' (Tyler 1969:2).

Conklin, one of the first to work with folk taxonomy, clearly indicates its relational nature. Indeed he defines a folk taxonomy as a system of items 'related by a hierarchical inclusion' (1962:49). Unfortunately, this aspect of folk taxonomies has been generally obscured in Anthropology by the convention of representing them by box diagrams. Figure 1 shows a two-level taxonomy, indicating that both canaries and robins are kinds of birds.

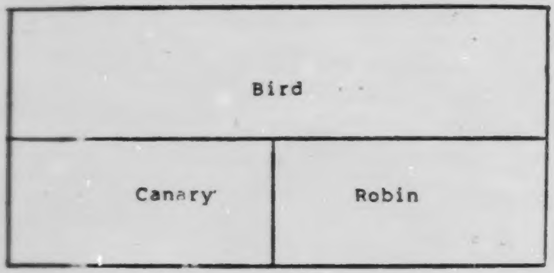


Fig. 1. Box Diagram.

Precursors who began to see semantic networks as systems of interconnected relations are Williams (1966) and especially Frake (1964).

Frake bases his theory on a set of questions used for eliciting folk knowledge:

?k - What kind of X is it?

?w - What is X (a kind of)?

?u - What is X used for?

?i - What is the ingredient of X?

?p - What (separable/separated) part of X is it?

?s - What does this come from?

Some of these questions, he notes, are potential inverses. For example ?k and ?w are inverse to each other in the sense that if lion is the answer to the ?k question 'What kind of animal is it?' then animal is the answer to the ?w question, 'What is a lion?' From the paired questions ?k and ?w, Frake derives a bi-directional relation or interlinkage, as he calls it, ?k/?w, which is equivalent to the species - genus relation of folk taxonomy.

Frake proposes a schema consisting of five bi-directional relations, all derived from paired questions which are potential inverses:

?k/?w species - genus
?k/?u species - use
?i/?u ingredient - use
?p/?s part - source
?u/?s use - source

He does not claim that this set is exhaustive. It does, however, provide a method for deriving semantic relations directly from elicited data. Figure 2 contains a small semantic network of terms related by Frake's interlinkages.

Williams' semantic network deals with the intersection of Japanese food, plant, season, and weather categories (1966). The relations relevant here are KIND, PART, NAME. (There are others that are not as relevant to our work.)

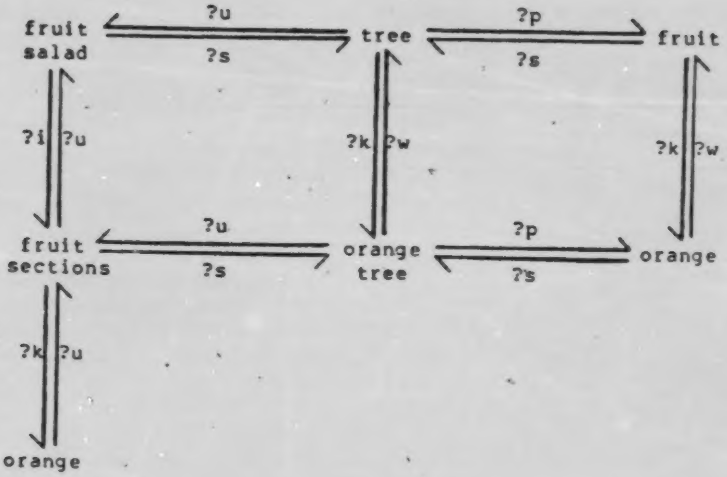

fruit salad
?u
?s
tree
?p
?s
fruit
?i
?u
?k
?w
?k
?w
fruit sections
?u
?s
orange tree
?p
?s
orange
?k
?u
orange

Fig. 2. Frake's Interlinkages.

Except for a minor critique of Frake's representation by Werner et al. (1974) (in which Frake's system is translated into Werner's with some adjustments to the direction of the arrows representing the relations), this kind of investigation was not followed up by others.

Casagrande and Hale (1967) were pioneers in the area of lexical-semantic relations with their work in linguistic anthropology. As part of a study of dialect variation Hale collected folk definitions by asking a single informant, Luke

Preston, to give informal verbal definitions of 800 terms in Papago, an American Indian language spoken in southern Arizona. These definitions were then grouped by first analyzing each complex sentence into simple sentences. Each sentence was then further reduced to a binary relation. Thus the definition of wolf, 'they are rather like coyotes, but they are big,' was broken into two simple sentences. Then the first was analyzed as an example of comparison (wolves are like coyotes), the second as an attributive relationship (wolves are big). Using this procedure Casagrande and Hale isolated thirteen basic lexical-semantic relations from the original complex definitions obtained from their native informant. These relations appear as the first thirteen relations in Table I. The relations are arranged in the order of frequency of appearance in the Papago sample. Each relation is accompanied by the description that Casagrande and Hale used as a basis for classification and by an example of the relation in English translation. Their paper contains a deeper analysis of each relation and many more examples in both Papago and English.

In search of evidence for the universality of the relations which they had identified in the Papago sample, they took another novel step: they looked at the literature in psychology. They compared their list of relations with the stimulus response pairs from the word-association tests

TABLE I: RELATIONS OF CASAGRANDE AND HALE

RELATION	DESCRIPTION	EXAMPLE
1. Attributive	x is defined with respect to one more distinctive or characteristic attributes Y.	*burrowing owl;* 'but they are small; and they act like mice and they live in holes.'
2. Contingency	x is defined with relation to a usual or necessary concomitant Y. There are really two notions: a) x usually or necessarily follows Y. b) Y is a usual or necessary concomitant of X.	a) *to get angry:* 'when we do not like something we get angry.' b) *to lightning:* 'when it rains, it lightnings.'
3. Function	X is defined as a means of effecting Y. (X is always a noun.)	*shovel:* 'with which earth is scooped up.'
4. Spatial	X is oriented spatially with respect to Y.	*nose:* 'it stands below our eyes.' *bucket:* 'in which we get water.'
5. Operational	X is defined with respect to an action of which it is a characteristic goal or recipient.	*bread:* 'which we eat.'
6. Comparison	X is defined in terms of its similarity and/or contrast with Y. Usually relates items on the same level of a taxonomy.	*wolf:* 'they are rather like coyotes, but they are big.'
7. Exemplification	X is defined by citing an appropriate co-occurent Y. a) where X is a verb, Y is a characteristic object or subject.	a) *to shine on, to give light* 'as when the sun goes over and gives us light.' b) *sweet:* 'as sugar.'

	b) where X is an adjective, Y is a noun to which it applies.	c) *horn:* 'cows have horns.'
	c) where X is a noun, Y is characteristic possessor.	
8. Class Inclusion	X is defined with respect to its membership in a hierarchial class Y.	*crane:* 'a bird.'
9. Synonymy	X is defined as being equivalent to Y.	*amusing:* 'funny.'
10. Antonymy	X is defined as being the negation of Y, its opposite.	*low:* 'not high.'
11. Provenience	X is defined with respect to its source Y. (The examples are all nouns.)	*milk:* 'we get it from a cow.'
12. Grading	X is defined with respect to its placement in a series or spectrum that also includes Y.	*Monday:* 'the one following Sunday.'
13. Circularity	X is defined as Y.	*to teach:* 'if someone teaches us we call it 'to teach'.'
14. Constituent	X is defined as being a constituent or part of Y.	A *cheek* is part of the face.
15. Coordinate	Word-association stimulus-response	*bread-butter* *needle-thread*
16. Clang	Word-association stimulus-response	*table-stable* *mutton-cotton*
17. Sequential	Word-association stimulus-response	*whistle-stop* *wish-bone*

Relations 1-13 are listed in order of frequency in the Papago sample which was the main focus of Casagrande and Hale's study. The other relations were suggested by English definitions, questions, and word-associations.

of Russell and Jenkins (Minnesota Norms, 1954). They found examples among the word association pairs for each relation on their list except circularity. On the other hand, there were some word association pairs not matched by any of their relations. These included part-whole (cheek-face), coordinate (needle-thread), clang response (table-stable), and sequential response (whistle-stop, wish-bone). These relations are also listed in Table I, although in their paper only the first is given a formal definition as a relation, the constituent or part-whole relation. They do not explain why the coordinate relation, or the others, did not deserve similar treatment. Webster's New International does recognize the coordinate relation, at least implicitly. It mentions thread in the definition of needle and has a separate entry for bread and butter.

It seems surprising that Casagrande and Hale were unable to find the constituent relation in the Papago sample. We note that English glosses of Papago originals do appear to be potential candidates for inclusion in this relation (1967:181):

> Horn: '...cows have horns.'
>
> Wing: '...any kind of bird has wings.'

Part of the problem may be that the list of words to be defined was originally chosen to exhibit dialect variation, not for studying standard forms of definitions. It is not clear if theirs is a complete list of relations for Papago or an appropriate list for English. Another problem may be that the formula 'A has a B' is the only method in Papago (back translation) to relate parts (B) to wholes (A). In English this is a relational inverse to the more regularly found part-whole relation.

The circular relation is a particularly interesting feature of the Casagrande and Hale system. They place in this category all those definitions that define a word in terms of itself or in terms of a word derived from the same morpheme by a productive derivational process, as in 'when something is sitting nearby, we say "near" ' (1967:184). While they record these examples as they do the others, they express a rather negative attitude toward them. Some examples may well be due to temporary failures of memory or articulation, but other examples seem to us to be particularly interesting as pointers to potential semantic primes as well as important derivational processes.

The Casagrande and Hale list of relations includes, as far as we know, all relations previously used in Anthropology and adds new ones. In addition, their paper has inspired further searches for relations in other languages (Rissell 1977; Manes undated).

Werner was also led to explore semantic relations by constructing folk definitions from texts (Werner 1965). The Anatomical Atlas of the Navajo (Werner, Begishe, and Austin 1971) is based on folk definitions and is structured by the part-whole relation. He used folk taxonomies as well, but he was one of the first to claim, in his work on field methods for ethnoscience, that taxonomies alone are not enough (Perchonock and Werner 1969; Werner and Fenton 1970). From his ethnoscience data Werner (1969) abstracted a minimal set of universal atomic lexical-semantic relations with taxonomy playing an important role. Complex relations are expressed in his system in terms of this language-universal minimal set. Using methods from computer science he has designed a 'synthetic informant' with a lexicon structured by these relations (Werner 1978). Taking advantage of the model-building techniques of artificial intelligence, he has developed a unified memory model (1974).

The most recent complete description of Werner's system integrates the atomic relations of taxonomy (T) and modification (M) with the sequential relation (Q). (See Werner and Topper 1976.) These relations he calls 'the basic cement of the organization of cultural knowledge and memory' (1974:17).

The relation of taxonomy (T) is exemplified in English by the sentence 'A canary is a (kind of) bird' and is written (canary) T (bird). It can also be represented in Werner's diagrams by a directed arc labelled T. (See Figure 3.)

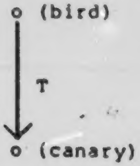


Fig. 3. Werner's Taxonomy Relation.

The relation of taxonomy (T) is transitive. That is, if 'a canary is a bird', and 'a bird is a vertebrate', then 'a canary is a vertebrate'. Some deductive capacity of the network is immediately accounted for by assuming all possible connections due to transitivity as given in Figure 4.

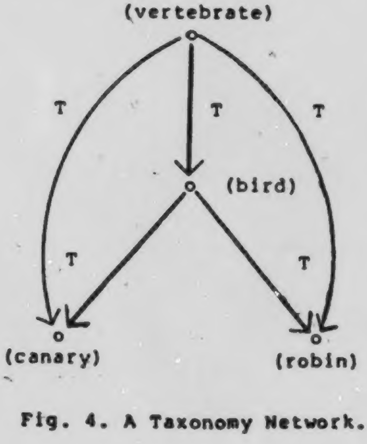


Fig. 4. A Taxonomy Network.

Werner (1972a) proposes a matrix representation of taxonomies in which the transitivity of T and the deductive capacity become part of the matrix structure, i.e., each level of a taxonomy corresponds to a dimension of the matrix.

Werner's modification relation (M) is used to represent concepts like 'a yellow bird'. The modification relationship between the modified term (bird) and the modifying term [yellow] is expressed in the formula ((bird) M [yellow]), or diagramatically as in Figure 5.

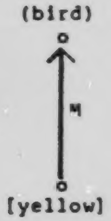


Fig. 5. Werner's Modification Relation. (*Yellow* appears in square brackets here because it is being used merely as a token in the representation of another concept.)

Werner's (M) relation necessitates the type-token distinction in the form introduced by Quillian (1968). In this schema the analogue to a dictionary entry (the left side) is a type. If the same term, a word or sometimes a phrase, appears in a definition (the right side of the entry), then it is a token. Thus in the modification relation the modified term is always a type and the modifier is always a token. In this context the tokens may be viewed simply as 'addresses' which 'point' to the 'home' taxonomy of their type. Types appear by convention in round parentheses, tokens in square brackets. The link between the token [yellow] appearing in Figure 5 and the type (yellow) appearing in its home taxonomy, the color taxonomy, is called a type-token link (TTL). Thus Figure 5 is only part of a larger network which appears in Figure 6.

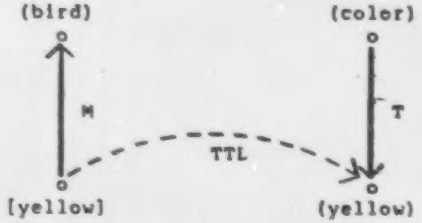


Fig. 6. Werner's Modification Relation with Type-Token Link.

When modification and taxonomy are combined as in 'a canary is a yellow bird', we obtain the formula (canary) T ((bird) M [yellow]). It can be diagrammed as in Figure 7, if we assume that structures of the form ((bird) M [yellow]) are treated as a unit.

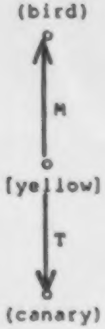


Fig. 7. Combination of Modification with Taxonomy.

Generalizing this picture to the open set of all attributes of canaries, Werner arrives at the MT schema or triangle of modification and taxonomy. This schema can be further elaborated by introducing a most easily accessible set of attributes, a set of retrievable attributes, and attributes that may be recognized but may never be elicited. Since different sets of attributes may enter the most accessible triangle for different concepts, this schema presumably can account for the observed variability of the central attributes. (See Section II.2.e.ii.) The above discussion may be represented in graphic form as in Figure 8 where the most accessible attributes always appear on the left in the diagram.

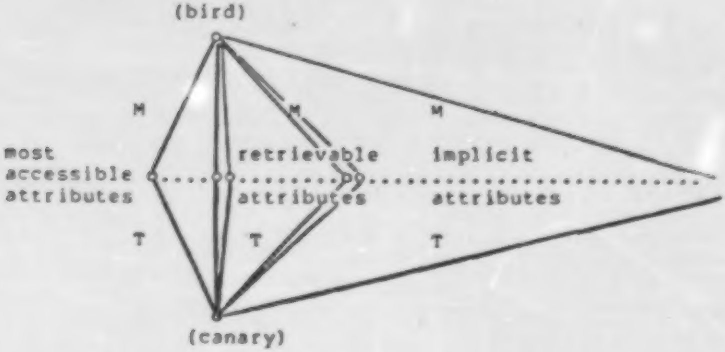

(bird)
M
M
M
most accessible attributes
retrievable attributes
implicit attributes
T
T
T
(canary)

Fig. 8. Sets of Attributes.

The queuing or sequential relation Q stands for serial order or sequence, as in (Monday) Q (Tuesday) and (taking the cap off the bottle) Q (drinking the beer). This relation is fundamental to the representation of Verbal Action Plans (VAP), such as directions for performing daily activities or recipes. For example, the plan for getting up in the morning can be expressed as a sequence of actions:

```
(waking up) (reaching over) (turning off  (getting out
                              alarm clock)     of bed)

    o ----------> o -----------> o ----------> o
          Q              Q             Q
```

In a recent publication Werner and Topper (1976) integrate Q into the MT schema and derive a new structure called the MTQ schema.

Complex relations are combinations of the atomic relations M, T, and Q. Synonymy S is defined in terms of taxonomy. Terms (a) and (b) are synonymous when (a) is a kind of (b) and at the same time (b) is a kind of (a). In other words (a) S (b) if and only if (a) T (b) and (b) T (a). Synonymy is therefore in effect a two-way taxonomy. The part-whole relation is a combination of M and T. For example, 'the thumb is part of the hand' is represented (thumb) T ((part) M [hand]), paraphrasable as 'the thumb is a hand-part'. The 'cause-of' relation is structurally identical. 'Lightning is a cause of thunder' becomes (lightning) T ((cause) M [(of) M [thunder]]), 'lightning is a thunder-cause'. By changing the preposition still other complex relations are included. 'Lumber is used for boats' becomes (lumber) T ((use) M [(for) M [boats]]).

Werner also uses logical relations to supplement the lexical-semantic MTQ relations. The augmented set includes N (not), C (and / conjunction), D (or / disjunction), and F (implication / if ... then). Werner (1978) has mentioned the possible inclusion of operators from modal logics such as can and may, but he has not yet followed up these suggestions with more concrete proposals.

Part-whole has not always appeared as a complex relation in Werner's work. The Navajo Anatomical Atlas, which is currently being used by the United States Public Health Service, (Werner, Begishe, and Austin 1971) contains a detailed representation of the Navajo views of anatomy and of disease. It is organized by two lexical-semantic relations, taxonomy and part-whole, both treated as primitives.

All of the representations of complex relations involve modification or attribution as a central factor. In Werner's schema the T and Q relationships and the complex relationships may all be interpreted as attributes that have to be taken into account in the definition of any term. At the same time, since they are linking tokens they can be used to build lexical-semantic fields. This field building may be extended to some complex relations, e.g. part-whole.

How do these type and token nodes and the relations linking them combine into a model of the lexicon? Werner was influenced by Bierman's (1964) 'star' model. (See Figure 9.) Imagine a dictionary with one page, a very large page on which all English words appear. Points represent words. Two points are connected by an arc whenever the words occur in generic sentences. The result is a 'word map'. To find the combinatory meaning of a word, locate the word on the map and follow the roads connecting it to other words. Each word, each term to be defined, is represented by a 'star of meaning,' with the word-node at its center and arcs leading out to the other terms in its semantic field.

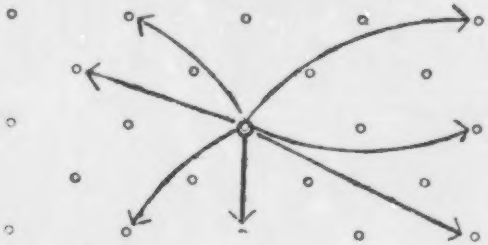


Fig. 9. Bierman's Star.

Werner views the lexicon as a network of type and token nodes related by M, T, and Q relations. Werner and Fenton (1970) define an extended Aristotelian definition within a taxonomy as the path from the node at the top of the taxonomy to the term to be defined plus the subtree dominated by that term.

In Werner's system episodic and semantic memory are unified. The MTQ schema represents occasional sentences as well as generic ones. The occasional sentence, 'Last Christmas John fell into the swimming pool' is represented as a particular fall of John's (fall(i)) which is taxonomically related to the generic (fall). (See Figure 10.) It is noteworthy that sentences in this system become incorporated into the larger classification and ordering of verbs.

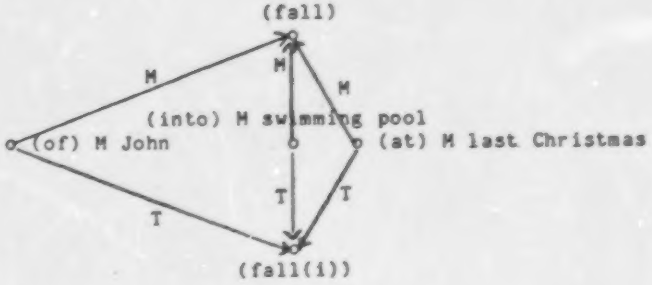


Fig. 10. Representation of Occasional Sentences in Werner's System. ('Last Christmas John fell into the swimming pool.')

The Q relation may also relate successive incidents in a narrative. Suppose Mary pulls John out before he drowns. If Mary's pulling John out of the swimming pool is (pull(j)), then (fall(i)) Q (pull(j)) represents a part of the story.

Prepositions are treated by Werner (1978) as modified types; they never occur as tokens. This is based on the insight that 'in the house' must be viewed as a kind of 'in' and not as a kind of house. Thus house modifies in. This leads Werner to conclude that all modifiers are attached to the modified 'head' term by case-like relations marked by prepositions. (Case relations are discussed in Section I.2.)

The lexicon in Werner's model is not a separate component but an integrated part of a complex three part memory: (1) the short-term memory is a linearizing device that may also contain a simple deductive capability; (2) the mid-range memory contains all processes that funnel knowledge into linear form; (3) long-range memory contains the conceptual classifications of all past experience as well as the classification of 'names' (i.e. the phonological component). Occasional and generic sentences are part of the same network in which generic sentences are inferred from repeated occasional information or experience. When one is told twenty times that a lion is a dangerous animal, one internalizes this information by creating new nodes and arcs. A brush with a lion in the wild could convince one immediately.

Werner and his students have applied this model to a study of schizophrenic speech (Werner et al. 1975).

Published examples of schizophrenic speech were shown to be derivable from the same MTQ networks which Werner posits as underlying normal speech. Differences from normal speech can be explained in this theory as the result of different strategies for tracing paths through the network or, sometimes, as the result of getting lost in the middle of a standard strategy. The same mechanism can be shown to account for some examples of metaphor.

Some kinds of sociolinguistic phenomena can also be explained in terms of Werner's model. He views context (Werner and Levis-Matichek in press) as a set of attributes which determine the appropriate use of a term or its synonyms. For example in the vocabulary of a herpetologist such contextual attributes (conditions of employment of a term) determine popular usage (e.g. hognose or hognose snake) versus scientific usage (e.g. heterodon). These attributes are modifiers in a taxonomy of 'names'. That is, in the popular usage the speaker must employ a popular name ((name) M (popular)); in the scientific usage, a scientific name ((name) M (scientific)). Obviously both modifiers 'popular' and 'scientific' may be complex, that is further internally structured.

Werner's work with relations is characterized by two extremes: a minimal set of relations and a very detailed memory model built up on this theoretical base. It is rich enough to represent both generic and occasional information and complete enough to explain many different kinds of human linguistic functioning.

2 SOME RELATIONAL MODELS IN LINGUISTICS

Traditionally, linguists have been interested in questions of semantic and lexical relations such as synonymy, antonymy, and modification. Lyons (1963, 1968, 1977) presents a complete overview of issues pertaining to lexical-semantic relations. He deals with such relations as hyponymy, synonymy, part-whole, various types of opposition, and grading.

More recently linguists working within a transformational generative grammatical approach have not specified the lexicon in such a way as to utilize semantic or lexical relations. They have not sought to elucidate the relationships among items in the lexicon. Rather, they have discussed the lexicon in terms of sets of binary features such as ± animal, ± human, etc., without indicating the relationships of features to each other or to the lexical item which they determine. (e.g. Katz 1966; cf. Eco 1976; Bierwisch 1971). Features within the Transformational Generative Grammar model were syntactically motivated, i.e., they were specified to the extent that they were needed for the functioning of syntactic rules.

While envisioning himself within a transformational generative approach, Fillmore (1968) attempted to alter the strictly syntactic nature of the deep structure of a transformational grammar by: (1) adding deep case relations (2) which were specified by the verb choice in a sentence. Fillmore's changes resulted in a verb-first or verb-favored deep structure where the lexical listing of the verb is specified as to what cases it can/must take (as compared to the binary feature approach mentioned above which was largely noun-dominated and for which verbs proved to be problematic). He was influenced by the work of Gruber (1967) which provides an extensive examination of verbs of motion and introduces the concept of semantic incorporation. For example, the verb pierce incorporates the preposition through because it is contained in the meaning of pierce. Some verbs incorporate cases (see below).

Fillmore's deep cases are not to be confused with grammatical relations such as 'subject of', 'object of', which are to be specified inherently by the rules of the transformational generative grammar. Deep cases are semantic relations which obtain between a verb and the nouns that appear with it in semantic structure. Fillmore (1968:24) lists the following deep cases as those which are most important:

Agentive (A)	The case of the typically animate perceived instigator of the action identified by the verb.
Instrumental (I)	The case of the inanimate force or object causally involved in the action or state identified by the verb.
Dative (D)	The case of the animate being affected by the state or action identified by the verb.
Factive (F)	The case of the object or being resulting from the action or state identified by the verb, or understood as a part of the meaning of the verb.
Locative (L)	The case which identifies the location or spatial orientation of the state or action identified by the verb.
Object (O)	The case of anything representable by a noun whose role in the action or state identified by the verb is identified by the semantic interpretation of the verb itself.

Verbs may differ in their case frames (i.e., the deep cases they can take) and how these cases are realized syntactically. The frame for the verb *open* is [____0+(I)+(A)], which contrasts with the case frame for *murder* [____0+D+(I)+A]. The parentheses indicate cases which are not obligatorily present. Thus Fillmore can account for the following list of sentences and surface case structures:

The door opened.	[________0]
John opened the door.	[______A+0]
The wind opened the door.	[______I+0]
John opened the door with a chisel.	[____A+0+I]

In some instances deep cases are not realized on the surface because of semantic incorporation, as in the verb *kiss* which semantically incorporates the instrument *lips*.

Since 1968, Fillmore's model has undergone considerable modification and has come to resemble a generative semantic approach (see below). Chafe (1970) has further elaborated this approach, indicating 3 types of verbs - action, state, and process - each of which takes different cases, and various derivational processes which alter these, thereby altering the case relationships between the derived verb and its nouns. for example:

'The dish broke.' broke = process
dish = patient

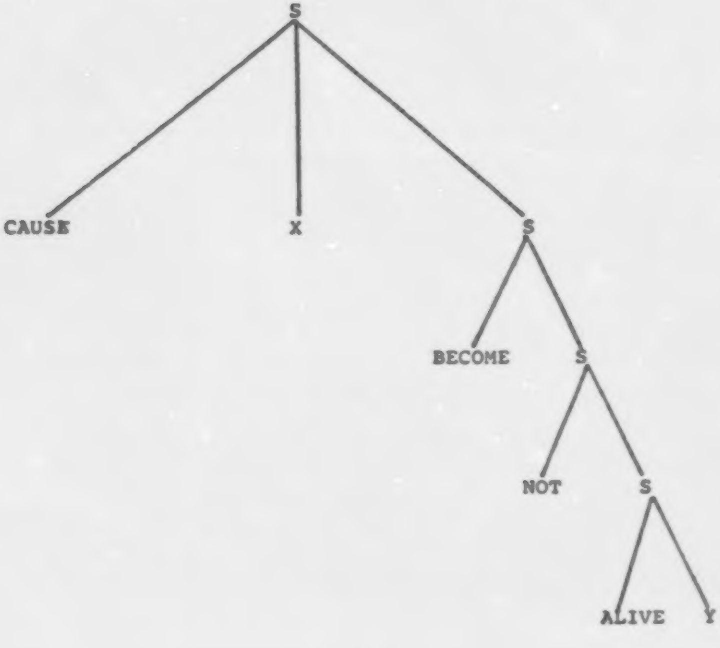
'Linda broke the dish with a sledgehammer.' broke + causative = process/action
Linda = agent
sledgehammer = instrument

'A sledgehammer broke the dish.' broke + resultative = state
dish = patient
sledgehammer = instrument

Additional elements which alter derivations of verbs from one type to another include: +cause, +inchoative.

Chafe's derivational approach, as well as Fillmore's later elaborations on types of lexical information (1971), parallels other changes occurring in Transformational Generative Grammar, namely the emergence of Generative Semantics. Generative Semanticists, like McCawley (1971), Lakoff (1971), Postal (1971), and Ross (1972), posit a verb-first or verb-focused underlying structure for sentences. This structure consists of a predicate and its arguments, where the arguments are determined by the predicate, and it resembles structures in symbolic logic. Generative Semanticists have looked at the lexical composition of verbs, positing series of semantic primes called atomic predicates which can be combined and recombined to form various lexical items whose relationships are shown in the transformational derivation. The analysis of *Kill* which appears in Figure 11 has become a classic example of this approach (much as *bachelor* was for semantic feature analysis, as illustrated in the Introduction). Note the atomic predicates CAUSE and BECOME. Note also that this tree can underlie both *kill* = *cause to die* and *kill* = *cause to become not alive*. In Generative Semantics, a small number of atomic predicates, i.e. *syntax*, take the place of relations as the links between lexical items following Weinreich's dictum that the lexicon is composed syntactically (McCawley 1970). Even though case relations and atomic predicates are embedded in largely syntactic theories, the generative semantic approaches contain much semantic information and are especially provocative in the treatment of verbs.

The richest theory of lexical relations in the linguistic literature, however, is that of Žolkovsky and Mel'čuk (1970). They have applied their theory in the construction of a dictionary, which they characterize as explanatory and combinatory. It is called *explanatory* because it explains the relationships between all the words in a given semantic field. It is termed *combinatory* because it includes all acceptable word combinations and syntactic government patterns. Their goals are practical lexicography and computational research. They do this within the structure of a more encompassing theory of language. Our


S
CAUSE
X
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ALIVE
Y

ig. 11. McCawley's Analysis of Kill.
(Reprinted with permission
from McCawley 1968:73.)

main concern here, however, is with their system of lexical-semantic relations.

The Explanatory-Combinatory Dictionary (ECD) which they developed is designed to contain all the grammatical and lexical information necessary to enable a novice speaker of Russian or, eventually, a computer program to synthesize fluent Russian text automatically from a few simple underlying words.

The dictionary is based on the methods for automatic paraphrase and 'semantic synthesis' of Russian from underlying trees developed by Žolkovsky and Mel'čuk (1970). The dictionary representation has four distinct levels:

1. Deep Semantics
2. Deep Syntax
3. Surface Syntax
4. Morphology

Levels one and two contain language universal information. The representation of deep semantics consists of universal semantic relations, which can have a variety of surface realizations within and across languages. (See Table II.) The deep relation Magn, for example, can be represented universally as Magn(x) = y at the level of deep semantics, while its surface syntax representation in English reflects language specific variability:

TABLE II - RELATIONS OF APRESYAN, MEL'ČUK, AND ŽOLKOVSKY

	Name	Description	Example
1.	Syn	synonym	Syn(to help)=to aid
2.	Conv	conversive	Conv(to buy)=to sell
3.	Anti	antonym	Anti(beautiful)=ugly Anti(friend)=enemy Anti(to love)=to hate
4.	Gener	name of the genus with respect to C_0	Gener(blue)=color
5.	S_0	noun which coincides with C_0 in meaning	S_0(to move)=movement
6.	A_0	adjective which coincides with C_0 in meaning	A_0(sun)=solar
7.	Adv_0	adverb which coincides with C_0 in meaning	Adv_0(critical)=critically Adv_0(meaning)=in meaning
8.	V_0	verb which coincides with C_0 in meaning	V_0(death)=to die
9.	S_i	generic name of the first, second, third, fourth participant in the situation	S_1(to sell)=seller S_2(to sell)=goods S_3(to sell)=buyer/customer S_4(to sell)=price
10.	S_{mod}	noun denoting the mode of action	S_{mod}(to write)= handwriting S_{mod}(to write)=style
11.	S_{loc}	noun denoting the place of C_0	S_{loc}(arrows)=quiver S_{loc}(action)=scene
12.	S_{instr}	noun denoting the instrument of C_0	S_{instr}(to think)=brain
13.	S_{res}	noun denoting the result of C_0	S_{res}(to hunt)=bag
14.	Sing	word meaning a single item or instance of C_0	Sing(news)=item

15. Mult	word denoting totality or aggregate	Mult(sheep)=flock
16. Cap	name of head	Cap(tribe)=chief
17. Equip	name of staff or personnel	Equip(gun)=crew
18. Figur	standard figurative designation of C_0	Figur(passion)=flame
19. Centr	name of central, culminating part	Centr(life)=prime
20. A_i	generic attribute of first, second, participant in situation	A_1(to know)=aware A_2(to know)=known/familiar
21. $Able_i$	generic definition of first, second,... potential participant	$Able_1$(to burn)=combustible $Able_2$(to eat)=edible
22. $Qual_i$	name of quality involving participants	$Qual_1$(to surprise)=unusual $Qual_2$(to understand)= obvious
23. Magn	attribute denoting 'very', to a great extent	Magn(to frighten)= to terrify
24. Plus	attribute denoting 'more, in a greater degree'	IncepPlus(tension)= to mount
25. Minus	opposite of Plus	IncepMinus(temperature)= to drop
26. Ver	attribute meaning right, proper	Ver(pride)=justifiable
27. Bon	attribute meaning good	Bon(aim)=lofty
28. Loc	appropriate preposition for noun C_0	Loc(list)=on
29. Copul	copula, link verb	Copul(victim)=to fall
30. Pred	$Copul(C_0)+C_0$	Pred(near)=to neighbor
31. $Oper_i$	verb connecting first,	$Oper_1$(support)=to lend

	second,...participant in situation with name of situation	Oper_2(support)=to receive
32. Func_i	verb connecting name of situation and name of participant	Func_1(silence)=to reign Func_2(blow)=to fall
33. Labor_{ij}	verb connecting name of ith participant in function of subject with jth participant in function of object	Labor_{12}(torture)=to put to
34. Caus	verb meaning to act in such a way that C_0 comes into being	Caus(crisis)= to bring about
35. Perm	verb meaning to permit, to make it possible to	Perm(to fall)=to drop
36. Liqu	verb meaning to act in such a way that C_0 ceases, Liqu=AntiCaus	Liqu(mistake)=to correct
37. Incep	verb meaning to begin, used only in complex lexical functions	IncepFunc_0(war)= to break out
38. Cont	verb meaning to continue	ContOper_1(silence)=to keep
39. Fin	verb meaning to cease, to stop	FinOper_1(love)= to fall out of
40. Perf	the perfective, standard expression is perfect aspect of verb	Perf(to study)= to have mastered
41. Result	the resultative	Result(to study)=to know
42. Fact	verb meaning to become a fact	Fact(dream)=to come true
43. Real_1^i	verb meaning to make real, subject is ith participant	Real^1(program)=to adopt Real^2(program)=to carry out
44. Prepar	verb meaning to prepare	Prepar(table)=to lay

45. Degrad	verb meaning to deteriorate	Degrad(teeth)=to decay
46. Imper	idiomatic imperative	Imper(silence)=to shut up
47. Son	verb denoting typical sound produced by C_0	Son(dog)=to bark

Magn(educated) = highly educated

Magn(armed) = well armed

Magn(beautiful) = very beautiful

The deep semantic relations are of various types. There are six syntactic-semantic relations. Four of these relate the verb and its arguments: a subject relation, a direct object relation, and two other object relations. There is a coordinate relation linking connected items of similar function. Finally there is an attributive relation relating adjectives to nouns and adverbs to the verbs and adjectives they modify.

In addition, Apresyan, Mel'čuk, and Žolkovsky have relations between entries in their lexicon. They call these lexical functions, a central notion in their system. For example, the converse relation between buy and sell is expressed by the function Conv as Conv(to sell) = to buy. With each lexical pair there is also associated grammatical transformations specifying how to accomplish paraphrases. For example,

A sold B to C for D

is transformed to

B bought C from A for D.

More typical examples of converse pairs, they say, are active and passive voices of verbs. These are also listed in the ECD entries.

Another example of one of their functions, one that is derivationally based, is S_0 which relates verbs and their nominalizations: S_0(to analyze) = analysis, S_0(to die) = death. Then, corresponding to each syntactic-semantic relation relating verbs and their arguments there is a lexical function relating the verb and the characteristic filler of that argument slot.

S_1 (to analyze) = analyst

S_2 (to sell) = goods

S_3 (to sell) = buyer, customer (person to whom goods are sold)

S_4 (to sell) = price (amount for which goods are sold)

For any given word, there is a large family of lexical correlates, which are values of the lexical functions. From each family, one is chosen as an independent lexical item and put into what is called the depth lexis. All other words in the family can then be expressed in terms of the independent lexical item and the lexical functions. Thus the whole lexicon can be expressed in terms of a relatively small set (the depth lexis).

Apresyan, Mel'čuk and Žolkovsky have expanded the list of lexical functions in the ECD to include over fifty relations, and they outline ways to nest these relations to get many more. While they feel that they have captured the most important relations, their list is open-ended; whenever they notice a lexical regularity, they can add a new relation. Their relations (functions) are summarized in Table II.

3 SOME RELATIONAL MODELS IN PSYCHOLOGY

Most psychologists have been concerned with questions of reference, i.e, with relationships between real world objects and/or between these and words, rather than with relations between words. Even when stimuli used in experiments are, for example, lists of words, psychologists have treated these like labels for objects only or as objects in themselves, focusing on the stimulus characteristics of the words, e.g. their shape and length, or whether they are real or nonsensical. (Occasionally sharing of form class, e.g. nouns, verbs, etc., has been a salient characteristic.)

Only recently have psychologists been interested in the semantic relations among words, their organization, storage, retrieval, and acquisition. Two related impetuses have propelled some psychologists into interest in semantic relations: (1) analysis of responses to a group of tasks, such as word-associations, clustered recall of words, sorting of objects, and verbal definitions; (2) considerations of mapping or modeling of long-term or semantic memory. The former, task-related psychologists include Riegel, Deese, and

Miller, while the latter include Collins and Quillian, Kintsch, and Rumelhart, Lindsay, and Norman. In this section we take Collins and Quillian, Rumelhart, Lindsay, and Norman, Kintsch, and Riegel to be major representatives of psychologists using semantic relational models.

Psychological research involving language based on short-term memory has been the most common in psychology. Those who have attempted to model long-term memory processes have turned to computer scientists for their expertise on data storage bases which enable retrieval, question answering programs, etc. For their part, computer scientists seeking ways to represent knowledge have looked to similarly interested psychologists. The combination of the two fields (sometimes now referred to as 'Cognitive Science') can be seen most clearly in the work of Collins and Quillian (1972).

Using procedures such as elapsed reaction times or timed latencies of responses, Collins and Quillian have mapped out semantic distances between concepts in what they envision as a 'network'. Relative distances indicate accessibility of concepts for retrieval, and, inversely, accessibility as measured by the above methods indicates relative distances within the network. It can be objected that reaction time data can be seen to reflect either the length of search (i.e. pure distance) or an evaluation of the path involved in the search (i.e. decision strategies). Collins and Quillian, however, view short reaction times as indicative of what must be present in semantic networks as opposed to what must be inferred (i.e. not present but constructed).

The concepts in their semantic network are organized according to relations. These relations hold especially for nouns, but they seem less satisfactory for verbs. The fact that concepts are organized by these relations permits inferences to be made, on the basis of which new groupings and restructurings of long-term memory continually occur. Thus, these authors have proposed a model which allows for the utilization of experiences, as in human development, through feed-back (i.e., restructuring) while maintaining parsimonious storage. This is accomplished through the determination of what is there and what is inferred, by means of the measures of semantic distance.

Because of the union of practical considerations like parsimonious storage and psychological considerations like development, this model has been equally popular with computer scientists and psychologists.

Collins and Quillian's relations include:

1.	superset/superordinate (a transitive relation)	- frequently used and lesser supersets exist

2. subsets - most important, easiest strategy
3. similarity - properties of one concept applied to related concepts allowing for the same set of inferences as superset, but with less certainty; providing either a basis for distinguishing: (a pony is like a horse only smaller) or a basis for grouping: (a sheep is like a cow in that it chews a cud)
4. part - especially useful for geography, anatomy, architecture
5. proximity/adjacency - especially useful for geography, anatomy
6. consequence (causality) and precedence - especially useful for history and science
7. parent - for kinship

Negatives are either stored directly in memory or are inferable. Incompatible terms such as the color terms, *red*, *green*, are called 'contradictories' and represent contradictory values for the same property or attribute *color*. In Collins and Quillian's model, concepts can overlap as in Venn diagrams; and a consequence of the process of making inferences is that two concepts can be compared and found contradictory or similar, allowing for analogy and metaphor.

Rumelhart, Lindsay, and Norman (1972) have also developed a model of long term memory. The nodes in their networks represent concepts, events, or episodes. Primary concept nodes (types, roughly speaking) correspond to lexical entries. Secondary concept nodes (tokens) represent individual objects. Each secondary concept node (marked in the graph by angle brackets) is related to its primary node by the ISA relation (a koala ISA teddy bear). Concept nodes also enter into property relations. HAS is used for objects, 'John HAS pimples', while IS is used for qualities, 'John IS fat'. Thus, 'Teddy, the cross koala, has a black nose' would be represented as in Figure 12.

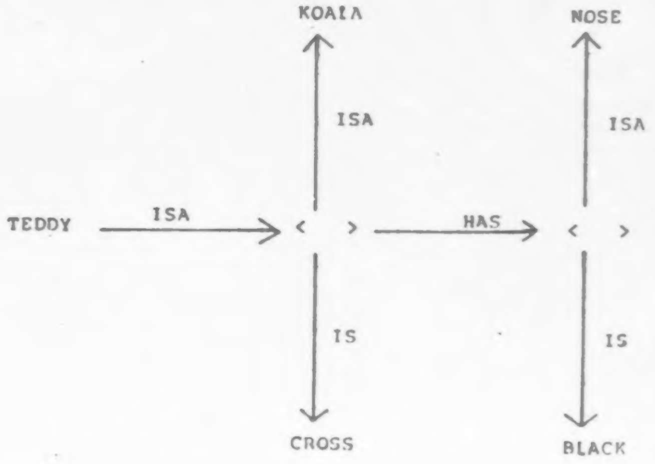


Fig. 12. Concept Relations in the Model of Rumelhart, Lindsay, and Norman. ('Teddy, the cross koala, has a black nose.')

Event nodes represent actions. Propositions are encoded by secondary event nodes (marked as circles in the graph in Figure 13). Each secondary event node is related to its primary event node by the ACT relation. As in Fillmore (1968) verbs or actions occupy a central position in the proposition and are related to arguments by relations which resemble cases. Thus, 'the lion licked the baby', becomes:

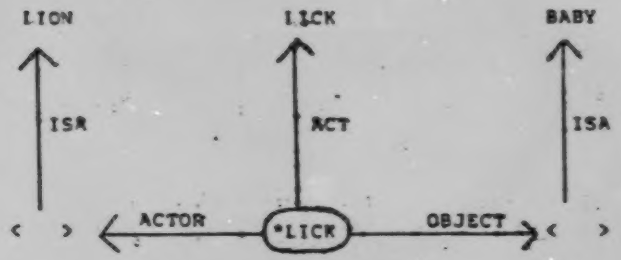


Fig. 13. Event Nodes in the Model Of Rumelhart, Lindsay, and Norman. ('The lion licked the baby.')

Other case-like relations used are INSTRUMENT, PATH, TIME, and LOCATION. Episodes are groups or sequences of event nodes. Event nodes within an episode are connected by propositional conjunctions like then and while. Rumelhart, Lindsay, and Norman treat definitions as an important part of their model of long term memory. (See Figure 14.) The relation DEF labels an arrow which leads into a definition of a term realized by the nodes and lines in the map of long-term memory.

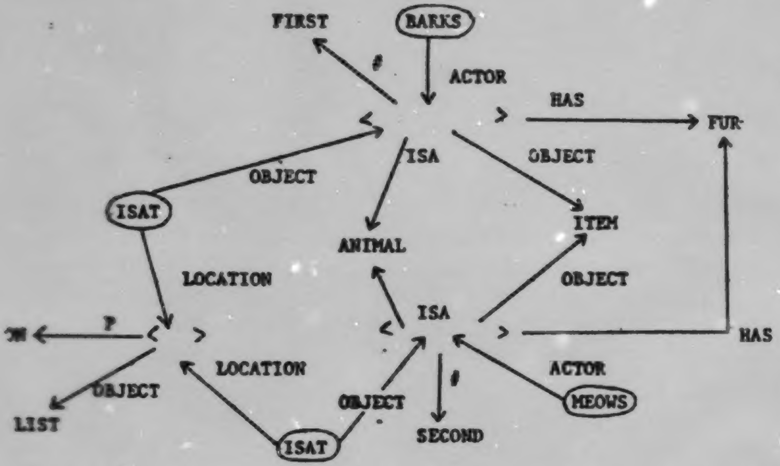

FIRST
BARKS
#
ACTOR
HAS
FUR
ISA
OBJECT
OBJECT
ISAT
ITEM
ANIMAL
LOCATION
OBJECT
ISA
HAS
P
LOCATION
ACTOR
OBJECT
OBJECT
#
MEOWS
LIST
ISAT
SECOND

Fig. 14. An Episode in the Model of Rumelhart, Lindsay, and Norman. (Reprinted with permission from Rumelhart et al. 1972:236, Part B.)

The simple conjunctions and, or, and xor (exclusive or) form a subset of the propositional conjunctions. Additionally, each relation has an inverse; when an ISA relationship is encoded into the data base, the corresponding ISA-INVERSE relationship is also encoded. Thus, during processing each arrow may be traversed in both directions.

This system provides for the creation of new concepts and relations from pre-existing ones by applying operators.

Operators include: the prepositional operator P which generates new concepts of time and location from old ones, as in before (breakfast) and before (noon) or under (water) and under (the chair); the relational operator 0 which replaces one relation by another, as in walk $\xrightarrow{0}$ slowly/walk; the qualifier Q which operates on concepts to produce new concepts, as in ball $\xrightarrow{Q}$ big (ball); and the quantifier # which specifies quantities, as in, dog $\xrightarrow{\#}$ three (dog). They expand quantification to include part, as in Spain $\xrightarrow{\#}$ part(Spain); unit, as in measurement $\xrightarrow{\#}$ inch(measurement); and amount, milk $\xrightarrow{\#}$ quart(milk).

Rumelhart, Lindsay and Norman (1972) are more closely mapping actual language; and their network is a series of pathways representing sentences and their interrelated parts. Retrieval involves choice among different pathways and movement along these pathways.

Kintsch (1972) has been interested in the psychological reality of propositions and how these propositions might be listed in memory. He uses parts of different linguistic approaches (see Section I.2):

semantic relationships from Lyons:

incompatibility	(color terms)
antonymy	(big-small)
hyponymy	(tulip-flower)

converse	(buy-sell)
complementarity	(male-female)
consequence	(fire-smoke)
synonymy	(heaviness-weight)

case relations as in Fillmore:

agent
instrument
experiencer
result
location
object

verb-first notation and atomic predicates from Generative Semantics:

CAUSE
BECOME
NOT, etc.

typology of verbs from Chafe:

state
process
action
action/process

Major detailed analyses are provided for nouns and verbs. Nouns have relations particular to them, such as Lyons' above, as well as other more general organizing relations. These latter include: IS-A-MEMBER-OF, which forms a set-inclusion hierarchy and is expressible in predicate nominals such as 'A is a B'. Kintsch warns that not all of these relations form trees, since there is no 'unique successor'. For example, in Figure 15, 'dog' may have two successors, 'mammal' and 'pet'.

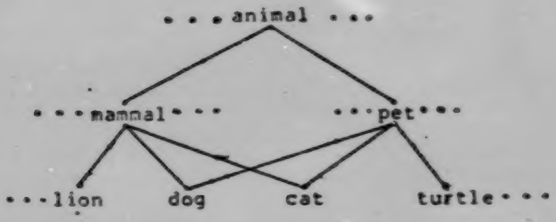


Fig. 15. Kintsch's IS-A-MEMBER-OF Relation. (Reprinted with permission from Kintsch 1972:257.)

The lexicon is partitioned in multiple ways, as in Figure 16, forming series of ANTONYMOUS N-TUPLES, sets of words which share superordinate terms.

Kintsch mentions the importance of the part-whole,

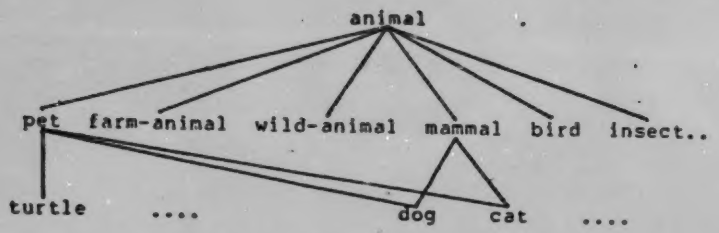


Fig. 16. Partitioning the Lexicon According to Kintsch. (Reprinted with permission from Kintsch 1972:268.)

ownership, and left-to-right relations from Raphael's SIR model (1968). He feels two relations necessary for general lexical organization are LOCATED, an ordered relation, e.g., 'the stove is in the kitchen', and PART-OF. The PART-OF relation is in some sense formally the same as the set-inclusion relation but the lexicon has many different part-of hierarchies which are unrelated, e.g. parts of the body and parts of automobiles.

Verbs are organized according to Chafe's typology and are stated in terms of predicate-argument notation. Propositions are listed as verb plus special cases where relations such as set inclusion apply to their arguments (i.e., the nouns fulfill special case relations to verbs).

Kintsch posits sets of rules such as inference rules which can handle the synonymy or antonymy of propositions. As in Collins and Quillian, the memory represents a small base of stored information (classified as above) by means of which a larger amount can be generated by inference or redundancy rules. These rules include the following types:

1. lexical transformation rules:

Fred bakes	Fred is a baker
Ada's virtue	Ada is virtuous

2. analogy rules to produce metaphor

   the fog enveloped the bridge like a moist blanket

3. compression rules (relate two propositions or compress and delete)

   the fog comes on little cat's feet

In a more recent book (1974) Kintsch attempts to include some real-world or experiential knowledge as well as dictionary entries in the meaning networks of semantic memory. For example: along with dictionary-type information on bear, an individual may also have 'the night the bear visited our tent' as part of the central meaning for bear; but 'dancing bears at the circus' may be accessible only after a memory search. Kintsch is trying to include in a semantic memory model two related problem areas: the connection of dictionary and real-world or encyclopedic knowledge, and individual variation in meanings. In his model he posits some of this information as more central (i.e. more immediately retrievable).

Kintsch (1977) and Rumelhart (1975) have developed story grammars for extended texts. Their grammars are composed of constituent categories and rewrite rules. Syntactic categories in rules for stories include 'events', 'episodes', etc. Both authors use propositional connectives such as AND, THEN, CAUSE. Unlike Werner these authors do not use the same set of semantic relations for both intrasentential and intersentential relationships. (Story or text relations will be discussed in III.6.)

Finally, the last psychologist who uses a relational semantic model in our discussion is set apart from the previous three by his research interests and methods. Riegel (1970) is interested in ontological and gerontological changes in vocabulary as seen in word-association and definitional responses.

Riegel has not focused on the mapping or simulation of long-term memory as have the psychologists we have discussed previously. He is concerned with the interrelationship of language and thought in the development and dissolution of cognition. He is interested in the construction of a truly psycholinguistic representation of meaning which could underlie language and thought. He is, consequently, less tied to actual language utterances and more interested in underlying semantic relations. Among psychologists, he has the most encompassing list of semantic relations.

These relations are divided into logical and infralogical. Logical relations are based on words thanselves (rather them objects, events, or qualities) and are derived by verbal abstraction. Logical relations are:

	Relation	Example
1.	Synonymity/similars	(zebra-horse)
2.	Antonymity/contrasts	(black-white)
3.	Superordination	(table-furniture)
4.	Coordination	(table-chair)
5.	Subordination	(animal-zebra)

Infralogical relations or physical relations are based on the denoted objects, events, or qualities and are a product of abstracting physical features from items. The infralogical relations are:

6.	Parts	(zebra-stripes, table-leg)
7.	Wholes	(horn-cow)
8.	Locations	(zebra-Africa)
9.	Preceding, contemporaneous,	(crash-hospital)

succeeding events

10. Substance (table-wood)
11. Quality (table-hard)

There are also grammatical or syntagmatic relations (the above being largely paradigmatic). Syntagmatic relations are derived from the linguistic context, representing response terms in Riegel's data, which are nouns, verbs, adjectives, and words preceding or following the stimuli.

Riegel calls a fourth set of relations Relations-of-Relations. These include 'symmetric conjunctions like AND, TOO, ALSO, AS WELL AS, etc., the comma in enumerations, and relative pronouns like WHICH, WHO, and THAT' (cf. earlier logical relations). For example (1970:394):

Coordination: (EAGLE-FLIES and (RABBIT-RUNS)
Super/sub-ordination: (RABBIT-RUNS) which (EAGLE-HAUNTS)
or RABBIT which (EAGLE-HAUNTS) - runs

Asymmetric conjunctions (IF-THEN, BECAUSE, BEFORE, AFTER, etc.) and relative adverbs (WHERE, WHEN, WHY, etc.) represent spatial, temporal-causal relations (cf. earlier infra-logical relations). For example (1970:394):

Spatial: (HOUSE-BURNS) where (JOHN-LIVES)
Temporal-Causal: if (EAGLE-FLIES) then (RABBIT-RUNS)

Thus, relations-of-relations can accommodate extended language, which may include other embedded intralingual relations.

Riegel has stressed his belief that the relational model can include and account for current and future development in three important areas: (1) formal properties such as symmetry, transitivity and reflexivity; (2) cases; (3) information from developmental studies such as Brown's (1973). Yet he leaves these suggestions undeveloped.

In discussing the data from Feifel's research on definitions (Feifel 1949; Feifel and Lorge 1950) Riegel discusses Feifel's classification of definitional types which he lists as follows:

Types	Data
generic definition (by synonym)	eyelash = hair over the eye or that protects you
functional definition	straw = hay that cattle eat
use and description	banana = yellow and you eat it
explanations	priceless = worth a lot of money
illustrations	priceless = gem
repetitions	puddle = puddle of water
demonstrations	

Riegel notes the ambiguities in these types, e.g.

function and use being in two types, but it is not clear how Riegel would account for some of these relationships with his set of relations, such as function or explanation.

Riegel's major aim was to highlight the changes with age which occur among definitional types. For example, use of generic definitions (synonyms) increases until eleven years of age in these data, but then changes little; there is a less marked increase in explanations, which stops in adulthood; uses and decriptions become less used as children get older, but reappear as important in late adulthood. In general, Riegel found that, translated into his semantic relations, he could note the increased use of multiple relations which mark cognitive reorganizations throughout life.

Norlin (1976) has applied Riegel's relations to children's definitions in his study of developmental lexical semantics. On the basis of his data (48 children, ages 3-6), he amends Riegel's list as follows: to include 'number', 'agentive function (animate subject)', 'recipient function (inanimate subject)'; to divide 'part' into 'intrinsic (inalienable) part' and 'extrinsic (alienable) part'; to delete 'antonymy', which does not occur in his data.

Before closing this section of our work on psychology we would like to mention Language and Perception (1976) a major work on the nature of the lexicon by Miller and Johnson-Laird. The authors review and synthesize much of the current work which pertains to lexical entries. Differentiating between conceptual and lexical information, on the one hand, and perceptual and semantic information, on the other, Miller and Johnson-Laird propose a theoretically inclusive yet pragmatic thesis. To do justice to the complexity of their model would be beyond the scope of this survey.

While Miller and Johnson-Laird discuss many of the same authors and disciplines as we have in our survey, as psychologists their aim is to 'formulate a psychological theory of lexical knowledge' (1976:2) or psycholexicology (as such an area would be called). Consequently, the authors include much experimental psychological literature which has not been covered in our survey.

Their goal is to join the often separated aspects of meaning - reference and sense, or the 'external' and 'internal' relations of words (ibid.:7) - by incorporating perception and semantics, constructing 'a theory in which words and percepts are not linked directly to each other but in which both provide avenues into a conceptual realm' (ibid.:8).

Their method is to explore various theoretical questions (e.g., are either perceptual features or semantic features alone sufficient to designate lexical knowledge? what is the relationship of lexical knowledge to conceptual knowledge?) by means of tests on language and to apply their conclusions to various sections of lexical knowledge (e.g. deictic verbs of motion, verbs of vision, kinship). Therefore, at the end, the authors arrive at a theoretical position after having provided several very detailed analyses of lexical areas. The book can be appreciated for these indepth studies of particular lexical domains as well as for its excellent overview of psychological and linguistic theories pertaining to the lexicon.

4 SOME RELATIONAL MODELS IN COMPUTER SCIENCES

Several highly significant experiments in natural language processing with semantic relations were carried out at Massachusetts Institute of Technology under the general direction of Minsky. One of these experiments was performed by Raphael (1968) who developed a question answering system called SIR (Semantic Information Retrieval program). It combines a general semantic network representation with a relational calculus which makes inferences. SIR inputs simple English sentences, translates them into node-relation-node form, uses a relational calculus to prove theorems, asks for more information if needed, and answers questions using these inferences. The relations which Raphael uses are:

Relation	Example
$X \subset Y$	(An X is a Y. A boy is a person.)
$X \in Y$	(X is a Y. John is a person.)
equiv[x;y]	(x and y are two names for the same thing.)
owng[x;y]	(Every y owns an x.)*
own[x;y]	(y owns an x.)
partg[x;y]	(An x is part of a y.)*
part[x;y]	(An x is part of y.)
right[x;y]	(x is to the right of y.)
jright[x;y]	(x is just to the right of y.)

*g=general or generic

Each relation R has an inverse $\bar{R}$. If aRb, then (R,b) is stored on the property list of a and ($\bar{R}$,a) is stored on the property list of b. For each relation there are axioms. Further axioms describe how different relations interact. For instance, SETR (set inclusion) has the following properties:

$\mathcal{T}[\subset]$ i.e., set inclusion is transitive

$\text{equiv}[x;y] \Rightarrow x \subset y$ (if x and y are nouns for the same thing, then x is a subset of y.)

$\alpha \in x \wedge x \subset y \Rightarrow \alpha \in y$ (if α is a member of set x and x is a subset of y, then α is also a member of y.)

The set relation interacts with the part relation as follows:

$$\mathrm{partg}[x;y] \wedge z \subset y \Rightarrow \mathrm{partg}[x;z]$$

$$\mathrm{partg}[x;y] \wedge z \in y \Rightarrow \mathrm{par}^{\sim}[x;y]$$

Despite all its obvious intelligence, SIR has some serious limitations. Its deductive system is not general enough. Raphael himself pointed out the necessity of generalizing the system so that new relations could be added and new axioms derived from their properties. Even with these planned improvements too much complex information had to be built into SIR's search programs. This kind of information is also semantic information. Some method is needed to express this information as data. Semantic representations must be devised for relations and axiom schemes as well.

Quillian (1968 and 1969), also working with Minsky, developed a memory model based on semantic relations. Quillian's semantic net consists of a collection of nodes connected by several different kinds of associative links as in Figure 17. For each word-sense there is exactly one type node. The type node points to the intertwined mass of nodes which represents its meaning. These nodes together form a single plane in memory. Figure 17 is the plane of PLANT2, the sense of plant which means 'apparatus used for any process in industry'.

Different senses of a given word are numbered. For example:

PLANT. 1. Living structure which is not an animal, frequently with leaves, getting its food from air, water, earth.
2. Apparatus used for any process in industry.
3. Put (seed, plant, etc.) in earth for growth.

In Figure 17, PLANT2 is a type node, but the other two nodes are token nodes. The dotted line from APPARATUS would point, if you could see the whole network at once, from the PLANT2 type node to the token node in the APPARATUS plane. The type node is circled to distinguish it from the other nodes, which are called token nodes. The dotted lines represent token-to-type links. These links point from token nodes to their type nodes. Thus they link planes to other planes. (See also Figure 13.) The token nodes in this plane are connected by three kinds of links: S(ubject), D(irect Object), and M(odifier). Quillian finds these three relations not rich enough to express all necessary semantic-syntactic information. He suggests replacing them either by Fillmore's deep cases or by prepositions.

This framework enables Quillian to define the full

PLANT. 1. Living structure which is not an animal, frequently with leaves, getting its food from air, water, earth.

2. Apparatus used for any process in industry.

3. Put (seed, plant, etc.) in earth for growth.

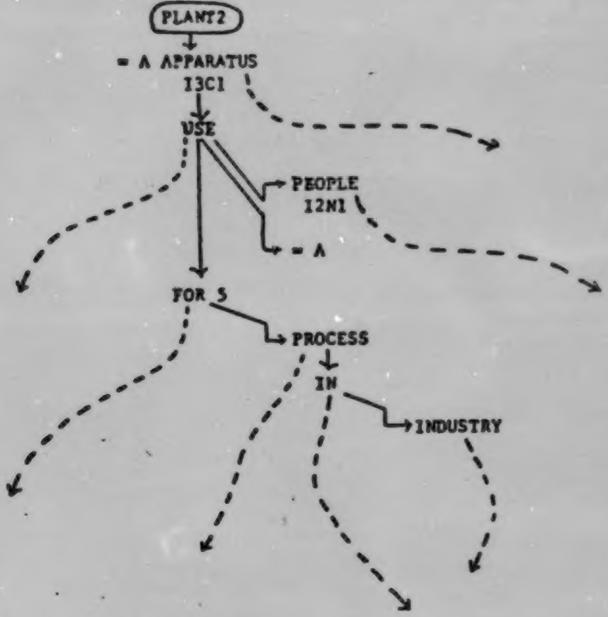

PLANT2
= A APPARATUS
13C1
USE
PEOPLE
12N1
= A
FOR 5
PROCESS
IN
INDUSTRY

Fig. 17. Quillian's Plane for PLANT2. (Reprinted with permission from Quillian 1958:236)

content of a word concept 'to include *all* the type and token nodes one can get to by starting at the initial type node'. Because he furnishes an algorithm for computing it, the definition of the *full word concept* is more precise than the notion of *cultural domain*, *semantic field*, or Apresyan's *lexical universe*. It may be too all-inclusive, however, since it is not clear to us whether the *full word concept* is distinct from the full lexicon.

R.F. Simmons also began to work with semantic networks in the early 1960's. He, with others, developed the PROTOSYNTHEX system (1964). His present model consists of a sophisticated network which encodes information by means of case relations and other semantic relations (1973).

Simmons and Slocum (1972) developed a program which generates paragraphs from a semantic network. The conceptual structure of the paragraph is represented by a collection of concept nodes (C1,C2,...). The lexicon is a collection of lexical nodes (L1,L2,...). Each concept node Ci is connected by the token substitution relation (TOK) to the appropriate lexical type node Lj. Thus a paragraph containing 'the garden swarms with bees' could be represented in part by Figure 18. The network also contains representations of relative time relationships like BEFORE and AFTER.

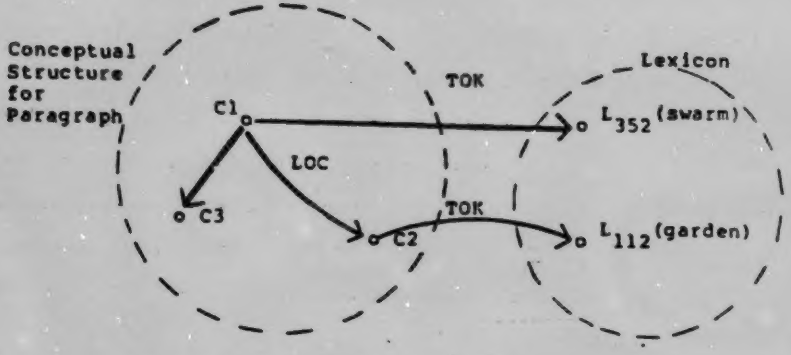

Conceptual Structure for Paragraph
Lexicon
C1
C2
C3
TOK
LOC
TOK
L_{352}(swarm)
L_{112}(garden)

Fig. 18. Simmons' Semantic Network.

More recently (1973), Simmons has used this kind of semantic network as the basis for further experiments in question-answering. In this process he developed several complex groups of conceptual and lexical relations. Concept nodes in his current model are linked by the deep case relations, by modality relations, by quantitative relations, and by attributive relations. (See Table III.)

Within concept node linkings there are several levels of attributive relations. The attributive relation MOD links substantive concepts and modifiers. During the analysis process MOD is refined to more specific relations such as SHAPE, SIZE, COLOR, POSSESSIVE, HASPART, ASSOC, PREP, or SUPerset. Similarly, the relation VMOD, which links verb and

TABLE III - RELATIONS OF SIMMONS

Relations Linking Concept Nodes	Examples
1. Deep Case Relations (from Celce-Murcia) CAUSAL ACTANT (CA1, CA2), THEME (T1, T2), SOURCE, GOAL, LOC (L1, L2, ...)	'John broke all seven windows with a red hammer, before he hit ...' Break: CA1 John T1 window CA2 hammer
2. Modality Relations (for verb nodes) TENSE, ASPECT, FORM, MOOD, ESSENCE, MODAL, ADJective, NP, MANNER, TIME	Break: TENSE past MOOD declarative ESSENCE positive
3. Attributive Relations (modified-rel-modifier) MOD specifies to SIZE, SHAPE, COLOR, POSSESSIVE, HAS PART, ASSOC, SUP, PREP. VMOD specifies to MANNER, TIME, FREQUENCY, INTENSITY, etc. Adjectives have DEGREE	Hammer: MOD red (becomes COLOR red) PREP with Red: DEGREE positive
4. Quantitative Relations Q, NEG, NBR, DET, COUNT	Window: Q all NBR plural COUNT seven
Relations Linking Lexical Nodes	
5. Set Relations SUP, SUB, EQ, PART OF, etc.	Ape: SUP animal Ape: SUB chimpanzee
Relations Linking Two Lexical Nodes or Two Concept Nodes	
6. Connectives OR, NOT, SINCE, BUT, AND, IMPLY, IMPLY BY, BECAUSE, THUS, BEFORE, AFTER, etc.	Break: BEFORE hit Napoleon: IMPLY Bonaparte
Relations Linking Concept and Lexical Nodes	
7. Token Substitution TOK	C1 TOK L53 (break) C2 TOK L15 (John)

adjective nodes with their adverbial modifiers, is specifi to MANNER, INTENSITY, etc.

Lexical nodes, on the other hand, are linked by se relations: SUP is used both for class inclusion (ape SU animal) and set membership (John SUP person). Some se relations can also be used to link concept nodes. Thus 'this woman is a mother' is represented in part by C1 SUP C2. Connectives which are used in the semantic generation program to link concept nodes (hit BEFORE run) are also used to link lexical nodes (Napolean IMPLY Bonaparte) for question-answering. Simmons' system of semantic relations is summarized in Table III.

Recently Simmons and his student Robert Amsler (1975 have performed some interesting experiments in computationa lexicology. They are looking at the organization of wor meanings, at hierarchical structures in particular, and a methods of transforming traditional dictionary definition into data structures that are immediately usable in natura language processing. They want to construct three kinds o semantic models: one for each sense meaning of a word; or for the context patterns that determine the choice of or word sense rather than another; and a third for the who set of words with definitions containing a given wor (1975:3).

From the tapes of the Merriam-Webster Pocket Dictionary prepared by Olney (1968), they have produced four extremely large data bases containing nouns, verbs, and adjectives: (1) Nouns from A to NAME (10,076,160 characters), (2) Nouns from NAME to ZYMASE (7,633,920 characters), (3) Verbs from ABANDON to ZOOM (5,847,040 characters), and (4) Adjectives from A CAPELLA to ZONAL (4,121,600 characters). They have developed software utilities which allow interactive retrieval of definitions and creation of subordinate data bases for any semantic domain under study. Definitions can be accessed by each word they contain or by combinations of words.

Amsler's (1977) study of verbs of motion, for example, began by retrieving all verbs with definitions containing the word move. He then divided them into categories depending on the sense of move involved. From this he constructed a semantic network for verbs of motion. The major lexical-semantic relations in this network (the arrows themselves) are called ISA and ISPART; they correspond to the relations we have called taxonomy and part-whole.

Amsler has also done a study of the semantic domain of vehicles (see Figure 19), in which the abbreviated nominal definitions of the Pocket Dictionary are parsed into verb-centered phrases. Indeed, Simmons and Amsler view the

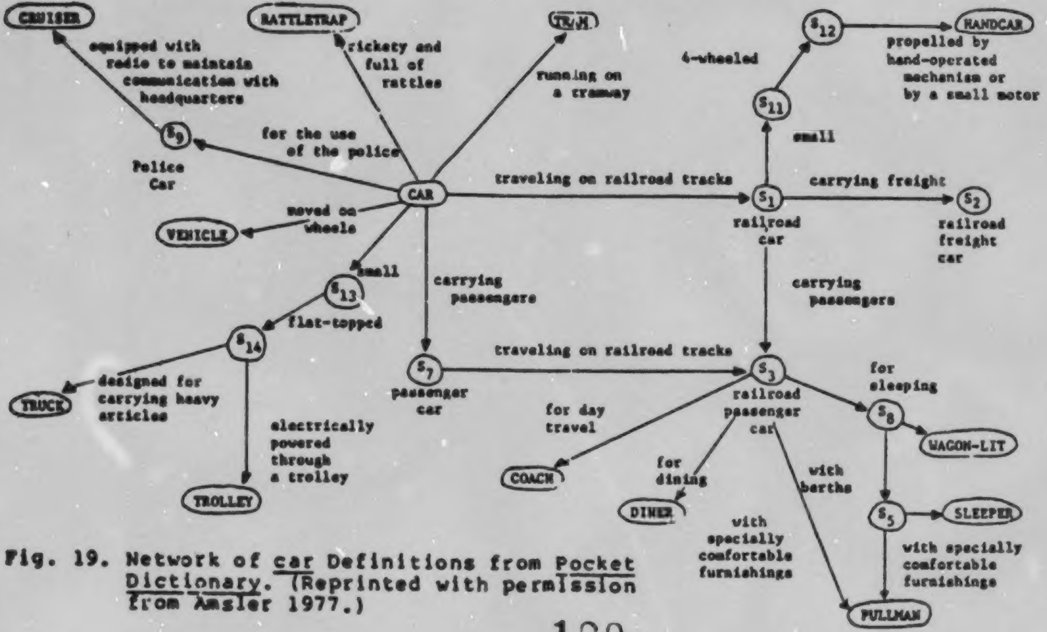

CRUISER
BATTLETRAP
TRAM
HANDCAR
equipped with radio to maintain communication with headquarters
rickety and full of rattles
running on a tramway
4-wheeled
S_{12}
propelled by hand-operated mechanism or by a small motor
S_{11}
small
S_9
for the use of the police
Police Car
CAR
traveling on railroad tracks
S_1
carrying freight
S_2
railroad car
railroad freight car
moved on wheels
VEHICLE
small
S_{13}
carrying passengers
carrying passengers
flat-topped
S_{14}
traveling on railroad tracks
S_7
S_3
designed for carrying heavy articles
TRUCK
passenger car
for day travel
railroad passenger car
for sleeping
S_8
WAGON-LIT
electrically powered through a trolley
COACH
for dining
with berths
DINER
TROLLEY
S_5
SLEEPER
with specially comfortable furnishings
with specially comfortable furnishings
PULLMAN

Fig. 19. Network of *car* Definitions from *Pocket Dictionary*. (Reprinted with permission from Amsler 1977.)

underlying structure of the lexicon as verb-centered. They consider verb hierarchies to be much more manageable than noun structures. They also find that every noun at the top of a hierarchy is an argument of some verb. This notion of the primacy of verb hierarchies is in strong contrast to the approaches of anthropologists like Werner who find the noun taxonomy to be a more natural starting point.

Simmons and Amsler are carrying forward promising experiments in automatic parsing of dictionary definitions. The enormous size of the data bases involved and the huge numbers of types which occur as tokens in definitions make this work extremely difficult. Olney has discovered that about fifty percent of the types in the Webster's Collegiate Dictionary occur as tokens in other definitions (personal communication).

Schank (1972, 1973, 1975a), working first at Stanford and now at Yale, has developed a model using semantic relations based on his theory of Conceptual Dependency. Underlying every sentence in a language, he asserts, there is at least one conceptualization. A conceptualization consists of concepts and relations among concepts. There are three elemental kinds of concepts: nominals, actions, and modifiers. He classifies as actions anything that an animate nominal can do to some object. All actions can be expressed in terms of twelve primitive conceptual ACT's, using conceptual dependencies, cases, and the relations of cause, time, and place.

There are several kinds of conceptual dependency. The predication of an attribute to a nominal is represented by the two-way dependency ⇔. Thus

John ⇔ tall	John is tall.
John ⇔ doctor	John is a doctor.

(These examples come from Schank, 1973; some are modified for simplicity.) The relationship between an actor and the action is also a two-way dependency ⟺. Thus, the sentence 'John moves' is diagrammed

John ⟺ moves.

There are four conceptual cases: OBJECTIVE (O), RECIPIENT (R), DIRECTIVE (D), and INSTRUMENTAL (I). These are all represented in the diagrams by a single arrow with the letter written next to it. For example, in Figure 20 ATRANS is the primitive ACT which describes abstract transfers of possession, ownership or control. Take is ATRANS where actor and recipient are identical. Give is ATRANS where actor and source are identical. (See Figure 21.) Many other verbs are represented in terms of ATRANS: steal, sell, own, bring, and catch are only a few.

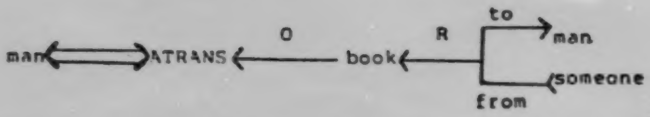

man
ATRANS
O
book
R
to
man
someone
from

Fig. 20. Conceptual Cases in Schank's Model. ('The man takes the book.' Reprinted with permission from Schank 1973:197.)

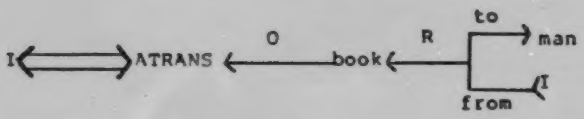
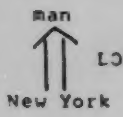
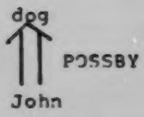

I
ATRANS
O
book
R
to
man
I
from

Fig. 21. One-way and Two-way Dependencies. ('I give a book to a man.' Reprinted with permission from Schank 1973:197.)

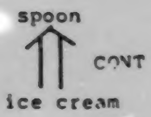
There are several one-way dependencies of noun upon noun. These are written:


man
LOC
New York

a man in New York


dog
POSSBY
John

John's dog


spoon
CONT
ice cream

a spoon of/with ice cream

All actions are assumed to have instruments. In the

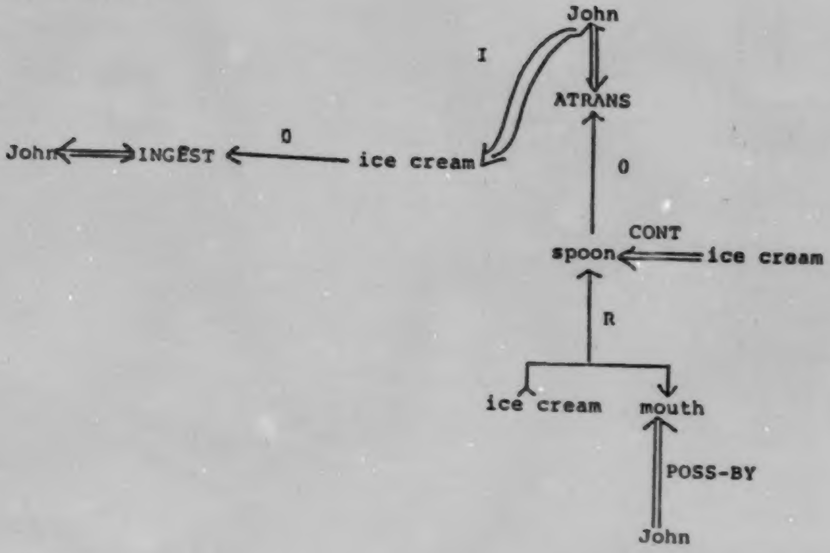
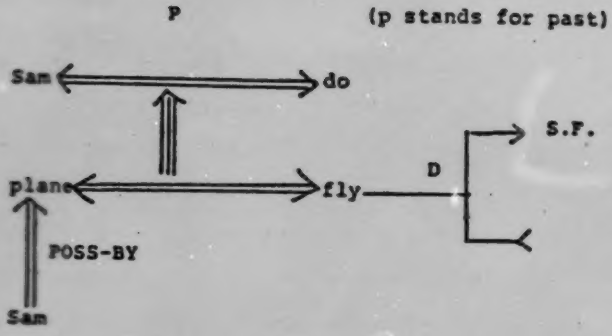

John
I
ATRANS
John
INGEST
0
ice cream
0
CONT
spoon
ice cream
R
ice cream
mouth
POSS-BY
John

Fig. 22. Schank's Representation of a Sentence. ('John eats the ice cream with a spoon.' Reprinted with permission from Schank 1973:201.)

ordinary use of language many aspects are presuppposed and are not specified on the surface. Schank's system represents as much of this information as possible immediately. The sentence, 'John eats the ice cream with a spoon', is represented as in Figure 22. This says essentially that John ingests the ice cream by means of a process in which John transfers a spoon containing ice cream from the ice cream source to his mouth. If the original sentence had said merely 'John eats some ice cream' with no mention of a spoon, this whole structure would have been formed with *spoon* replaced by *something*. The lexical entry for *eat* contains the whole structure (with variables X, Y, and Z in place of *John*, *ice cream* and *spoon*). The ACT's INGEST, ATRANS, etc., like the other semantic primitives, Schank insists, are not words but language-independent concepts.

The cause relation plays an important part in Schank's system. It has a special symbol $\Uparrow$. Schank analyzes 'x flies y' as 'x does cause y to fly' (1973:204). Figure 23 is the symbolic form of 'Sam flew his plane to San Francisco'.



(p stands for past)

Fig. 23. The Cause Relation in Schank's Model. ('Sam flew his plane to San Francisco.' Reprinted with permission from Schank 1973:204.)

Schank has developed a question-answering system MARGIE based on his theory and a story-processing system SAM (1975b) which uses networks held together by causal links. Schank's practical results are impressive. His claim that his system of relations is language universal and complete remains to be demonstrated.

There are two key experiments in understanding human speech based on semantic relational models. The relational model used at Stanford Research Institute is largely the work of Hendrix (1975; Walker 1978). Woods' team at Bolt, Beranek, and Newman in Cambridge, Massachusetts also uses a relational model (Woods 1976).

Relational theories have played an important part in the construction of computer programs which attempt to model natural language processing. Computer scientists have learned a great deal from models developed by social scientists.

In this chapter we have tried to give a brief survey of some key relational theories in all four disciplines: anthropology, linguistics, psychology, and computer science. In the next chapter we examine individual relations from several points of view.

CHAPTER 2

THE MAJOR RELATIONS

In this chapter we focus on some of the major relations which we glimpsed from the diverse perspectives described in Chapter I. There is a separate section for each major relation: Each section begins with a discussion of the place of the relation in Anthropology, Linguistics, Psychology, and Computer Science. Then we examine controversial issues surrounding the relation, its formal properties, and its connection with other relations.

Relations from the different disciplines which appeared to be similar were collected together in relation-groups. Table IV is a summary of these relations. Each row of the table corresponds to one of these groups of similar relations. For convenience, each row is assigned a name from the pool of relations. Each column displays relations from one of the major authors. We do not claim that the relations found in the same row are identical, but only that they are similar.

After the completion of this compilation and comparison,

TABLE IV - SUMMARY OF RELATIONS

Relation	Casagrande and Hale	Apresyan, Mel'čuk, and Žolkovsky	Simmons	Riegel	Werner
taxonomy	class inclusion comparison	Gener	SUP/SUB	superordinate/ subordinate	T
modification	attributive exemplification	A (generic attribute), Magn, Bon, Son S ?	MOD VMOD	intralogical relations	M
synonymy	synonymy	Syn Figur	EQ	synonymy	complex (limiting case of T)
antonymy	antonymy	Conv Anti	NEG	antonymy	
grading	grading coordinate sequential	Oper? Incep? Func? Liqu? Labor?	BEFORE/AFTER WHILE	preceding contemporan. succeeding events	Q
cause	contingency	Caus	BECAUSE/ IMPLY BY		
part/whole	consituent	Cap, Centr Sing, Mult Equip	PART OF HAS PART	parts/wholes	complex
provenience	provenience			substance	
case relations	spatial function operational	S_{loc}? S_{res}	LOC, Theme GOAL, Source Causal Actant	location	preposi-tions
text relations			AND, OR, NOT SINCE		plans with Q, etc.

it became clear that some relations merited more extensive treatment: taxonomy, modification, synonymy, antonymy, and grading. Each of these relation-groups is discussed in the following section. Other relations which warrant serious discussion are reviewed briefly in Chapter III.

1 TAXONOMY

The relation of taxonomy occupies an important position in lexical semantics. From the time of Aristotle this relation has been central to the process of definition. The classical form of a definition starts with a genus which is the term superordinate to the term to be defined. To this are added the differentiae which distinguish this term from related terms. Taxonomy is extended as a scientific tool in biological classification. Woodger (1937) and more recently Gregg (1954) have formalized this work. The uses of taxonomy have gained acceptance in anthropology, linguistics, psychology, and computer science.

TAXONOMY IN ANTHROPOLOGY

Anthropologists were perhaps the first to note the universal nature of human taxonomic classification. Folk taxonomies apparently occur in all human cultures (Berlin et al. 1966). Conklin made use of folk taxonomy in his work on

'Hanunóo Agriculture' (1954). Starting with Gregg's biological work, Conklin (1962) also made some of the first theoretical formulations in anthropology of the formal properties of taxonomies, more recently extended by Kay (1971). Casagrande and Hale (1967) call this relation class inclusion. Werner uses taxonomy extensively in The Anatomical Atlas of the Navajo (Werner, Begishe, and Austin 1971). It is a central issue in the study 'A Taxonomic Aspect of the Traditional Navajo Universe' (Werner, Manning, and Begishe in press). Although Werner, like other anthropologists, began with noun taxonomies, he has extended the taxonomy relation in more recent works (e.g. 1972b and 1978) to capture the relation between prepositional phrases and prepositions. As mentioned previously, he classifies 'in the house' as a kind of 'in'. Taxonomies also apply to verbs, i.e., a specific fall is a kind of fall.

TAXONOMY IN LINGUISTICS

Taxonomy first appears in linguistics in the early work on semantic field theory (see Ohmann's overview 1953). It is used in theoretical lexicography (Bierwisch and Kiefer 1970) and in practical lexicography (Apresyan, Mel'čuk and Žolkovsky 1970 call this relation Gener). Lyons (1968) uses the term hyponymy.

TAXONOMY IN PSYCHOLOGY

The taxonomic relation has been adopted by psychologists, too, but in this field of study it seems to travel incognito. Riegel (1970) uses the pair of terms superordinate-subordinate for taxonomy and its inverse relation. Kintsch (1972) calls the relation hyponymy and explains it as IS-A-MEMBER-OF. Rumelhart, Lindsay, and Norman (1972) call this relation ISA.

Psychologists have long been interested in category membership in the construction of standardized tests as well as research experiments. The role of superordinates has been stressed by Bruner (1973), Bruner, Goodnow, and Austin (1956), and others in concept formation and concept attainment. Much recent work has come from cognitive psychologists interested in the development of classes or concepts by children (e.g. Rosch 1973, 1978; Rosch et al. 1975, 1978; Anglin 1977) or the loss of categorization in aphasia (e.g. Lesser 1968). In addition, Piaget (1964), Miller and Johnson-Laird (1976), and others have emphasized the importance of both extension and intension in the formation of classes.

TAXONOMY IN COMPUTER SCIENCE

Computer models of memory have used taxonomy extensively beginning with Quillian (1968) and Raphael (1968). Raphael proposes taxonomies for both nouns and verbs. He uses formal axioms for taxonomy in the relational calculus, which forms the basis of his Semantic Information Retrieval program, SIR. In Simmons' (1973) model this relation is named SUP (superordinate). The computer question-answering system developed by Marx (1972) depends heavily on inclusion (i.e. taxonomy) and synonomy for its inference-making. Taxonomy is also the major relation in the OWL concept hierarchy (Martin 1975), but part-whole and typical-case relations are also used.

ISSUES IN TAXONOMY

REPRESENTATION

Establishing a satisfactory representation for taxonomic structures has not been simple. Taxonomies are often represented by tree structures, as in Figure 24. In this tree the branch between t_4 and t_1 represents the taxonomic relationship between these nodes, the fact that t_4 'is a kind of' t_1. Some researchers, notably Kay (1971), make a distinction between the names of particular objects and the

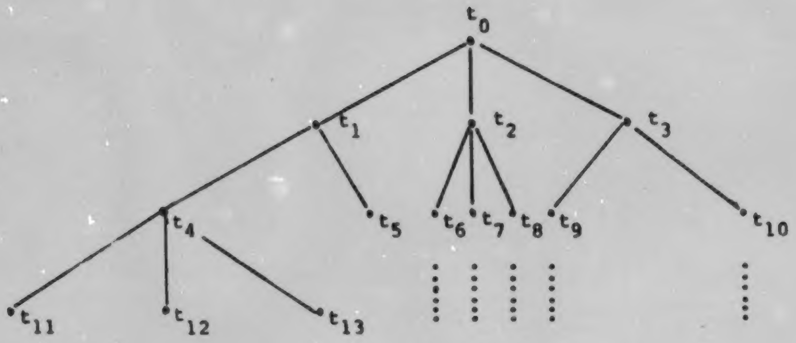


Fig. 24. A Tree Structure Representing a Multi-Level Taxonomy

objects themselves. In Kay's theory it is the objects themselves which are taxonomically related, not the names.

In some theories all taxonomies have a 'unique beginner' (t_0) which bears the name of the semantic domain to which all other nodes (t_1, t_2,....., t_i,...) belong. (See Figure 24.) But Colby (1966:89) and Lyons (1977;297ff) claim that folk-taxonomies do not always have a 'unique beginner'. Werner (1970) has shown that subordinate nodes, terminal nodes in particular, are often reachable by more than one path. That is, folk taxonomies often form networks rather than simple tree structures.

Anthropologists have also represented taxonomies by box diagrams, as in Figure 25. If taxonomy is a relation between labeled nodes, trees are a more satisfactory visual representation. Berlin et al. (1968) have suggested the possibility of unlabeled covert taxonomic nodes. Werner, however, feels that covert nodes should be used with caution, if at all. Since every new attribute can produce a covert node, nodes can proliferate without limit.

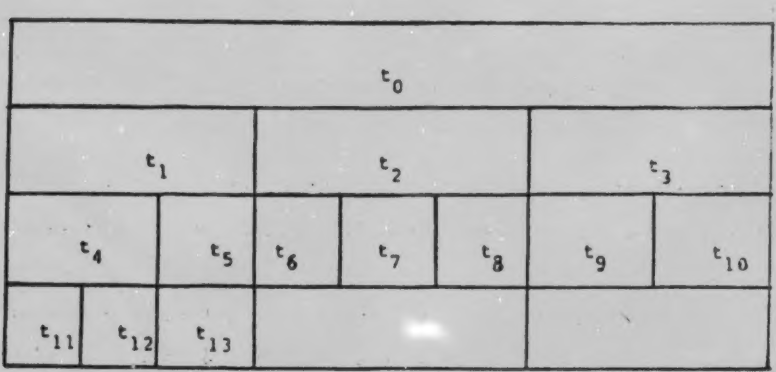


Fig. 25. A Box Diagram Representing the Same Taxonomy as Fig. 24.

SET MEMBERSHIP VERSUS CLASS INCLUSION

Another serious problem involves the possible distinction between set membership and class inclusion. Taxonomy may be viewed as encompassing both of these relations. Set membership relates the names of member individuals, such as *John*, to a particular set, such as *boys*. Class inclusion is a relation in which a set of individuals, such as *boys*, is viewed as a subset of a larger set of individuals, such as *people*. Does a model need to include both concepts or only class inclusion? If both concepts are retained, should they be treated separately or as two aspects of the same relation?

Some scholars limit discussion to a relation of class inclusion. For Lyons (1968) it is hyponoymy; for Apresyan, Mel'čuk, and Žolkovsky (1970) it is Gener; for Riegel (1970) it is superordinate-subordinate; and for Casagrande and Hale (1967) it is class inclusion.

Others include both aspects. Raphael (1968) and Hendrix (1975) distinguish between superset-subset (S) and member-element (E). Werner (1972a), Simmons (1973), and Maxwell (1974) do not make a formal distinction between set membership and class inclusion. Simmons uses SUP in both situations. Werner points out that both set membership and class inclusion are expressed by 'is a' in English (see also next section):

John is a boy.
A boy is a person.

In the representation that he uses, both are handled within the same tree. Terminal nodes or leaves such as t_{11}, t_{12}, and t_{13} in Figure 24 are members of the set t_4; and t_4 is a subset of t_1. The upper nodes of the tree are related to nodes above them by class inclusion.

Rumelhart, Lindsay, and Norman (1972) use ISA with substantives for the member - element relation, the subset - superset relation, and also for links between secondary concept nodes (tokens) and primary concept nodes (types). In contrast, token-type links for actions they treat as examples of the ACT relation. The instance of hit in 'John hit the ball' is represented by a secondary node *HIT and connected by an ACT link to the primary node HIT.

INTENSION VERSUS EXTENSION

The source of much of the foregoing controversy seems to be an underlying philosophical disagreement as to whether to take as primary the intension of a term or its extension.

The extension of a term is the set of things it names. Kay (1971), among others, treats the nodes of a taxonomic tree as collections of objects. From the extensional point of view, taxonomy relates member to set on the lowest level and subclass to class on higher levels. When A dominates B in a taxonomy, the extension of A, that is, the set of things named A, contains the extension of B. For example, the set of all birds contains the set of all canaries.

In contrast the intension of a term is the set of attributes it involves. From the intensional point of view, which Werner (1970) takes as primary, taxonomy relates sets of attributes, not sets of objects. As Lyons (1968) has noted, inclusion points in the opposite direction. When A dominates B, the intension of B (the set of attributes of B) contains the intension of A (the set of attributes of A). The term 'canary' contains all the attributes of 'bird' as well as many more. Werner and Topper suggest as an appropriate anthropological definition of the intension of a term 'the total cultural knowledge that some individual has about the proper application of the term in some context' (1976:17-18).

In a strictly intensional system like Werner's the set of attributes defining an individual is logically equivalent to a set of attributes defining a group of individuals. Thus, the distinction between set membership and class inclusion disappears in his model. Only outside of the model proper, in the 'real' world, does he see the necessity of separating the two. There the difficulty is overcome by quantification: that is, through some indication of 'John's' uniqueness versus the plurality of 'boys' or 'people'.

Models of mind-like behavior must clearly be able to function intensionally as well as extensionally. One of the achievements of Winograd's model (1972) is that it can accept a definition for a term in intensional form and put together a procedure for determining whether an individual is an instance of the term. Thus, extensions are derived from intensions by pointing (deixis) to specific individuals or groups of individuals who possess given intensions. In the body of work we have examined, only Lyons (1963, 1968, 1977) and Werner (1970) have confronted the extension/intension duality. Other workers may be influenced to emphasize one aspect of the concept of taxonomy because they focus primarily on extensions or primarily on intensions. In particular, some computer scientists who come from a mathematical background organize terms using extension only and look at taxonomy in terms of sets and subsets of individuals only. Failure to separate an intensional perspective from the extensional point of view creates confusion. In order to form a complete theory of taxonomy, it must be examined separately from both the intensional and the extensional perspectives.

FORMAL PROPERTIES OF TAXONOMY

The historical importance of the taxonomic relation results from its deductive power. This power derives from the transitive property. If (c) is taxonomically related to (b) and (b) is taxonomically related to (a), then (c) and (a) are also taxonomically related. If we know that lions are mammals and mammals are vertebrates, then we know that lions are vertebrates. In our notation the classical syllogism:

Socrates is a man
All men are mortal
Socrates is mortal

becomes, using T as a symbol for the taxonomic relation,

(Socrates) T (man)
(man) T (mortal)
(Socrates) T (mortal)

This type of syllogism is apparently as fundamental in the logic of nonwestern cultures and languages as it is in ours (Hamill 1974).

In addition to transitivity, taxonomy has other properties. In formal terms:

(i) T is reflexive. That is, if (a) is an arbitrary label for a node (also called a taxon), then (a) T (a) is part of the taxonomic structure.

(ii) T is not symmetric. That is, in general when (a) T (b) is part of the structure formed by T, then (b) T (a) is not. When both (a) T (b) and (b) T (a), we say that (a) and (b) are synonymous.

The graphic representation of taxonomies can be refined using these properties. Taxons are labeled nodes. The taxonomic relation is represented by an arrow rather than just a line (see Figure 26) to reflect the lack of symmetry in the relation. In accordance with an intensional view of taxonomy, the arrow always points from the more general to the more specific node. Empirically the arrow represents the frame '... is a (kind of) ...' or several similar sentences occurring in all natural languages.

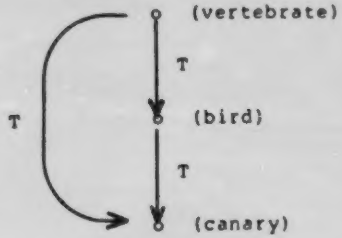


Fig. 26. A Partial Taxonomy Represented by a Directed Graph.

The graph structure is, strictly speaking, not a tree but a network. This is a consequence of the transitivity of the taxonomic relation. If (a) T (b), (b) T (c),...(y) T (z), then by repeated use of the transitivity property it follows that (a) T (z). If we set up a unit of measure on paths through the network, by assigning as distance between two nodes the number of arrows that must be crossed to get from one to another, then every node in the taxonomy is at a distance of one from the unique beginner.

CONNECTION BETWEEN TAXONOMY AND OTHER RELATIONS

Using the notion of intension, Werner (1970) has highlighted the close ties between taxonomy and modification. The intension of any subordinate node in the taxonomy can be obtained from the intension of a superordinate node by adding attributes, that is, by applying modification. Conversely, when a term is modified by adding attributes, a new subordinate node is created in the taxonomy.

The relation which Casagrande and Hale (1967) call *comparison* is also closely connected to taxonomy (*wolf*: '...they are rather like coyotes'). In their examples, the terms being compared are always taxonomic sisters like t_6, t_7, t_8 in Figure 24. Color terms, *red*, *blue*, *green*, *white*, *yellow* form such a set of sister nodes. Other researchers look at relationships between more distantly related nodes at the same taxonomic level. Bolinger refers to such terms as co-hyponyms (1975). Lyons (1968) classifies them as cases of incompatibility. (See also sections 4 and 5 on antonymy and grading.)

Collins and Quillian define a similarity relation which allows the transfer of properties from one concept to another. 'It allows the same set of inferences as superset, but with less certainty....If one knows a toad is like a frog and that a frog is an amphibian, then one can infer with some uncertainty that a toad is an amphibian' (1972:323). Lehrer (1974a) argues against a similarity relation and in favor of a more pragmatic use of similarity: 'Similarity of meaning is not stored information - what a speaker knows about his lexicon. Rather, similarity is something that is computed according to criteria that shift from one time to the next' (1974a:38). Such far-flung comparisons, as 'A is like B', are fundamental for the formation of similes, metaphors and folk-models (Werner et al. 1975) as well as for analogical reasoning (Rumelhart and Abrahamson 1973) and concept formation (Litowitz MS).

2 MODIFICATION

The classical form of definitions, as in Aristotle, contain differentiae which are attributes related to the genus or the superordinate node by the relation of modification. The notion of modification has found a variety of realizations.

MODIFICATION IN ANTHROPOLOGY

Casagrande and Hale classify as attributive any definition in which 'X is defined with respect to one or more distinctive or characteristic attributes Y' (1967:168). With such a broad definition it is not surprising that this category was the largest in their sample. All definitions of plants and animals in their Papago Indian data are at least in part attributive: most include at least two attributes; many have more than two. For example, ants are defined as 'those which go around: they will come out now because it will be getting warm; some are black and some are red; they get things here around the house and keep putting them away in their hole'.

Casagrande and Hale divide the attributive relation into five subcategories:

a) *Stimulus properties*. (These may be either *intrinsic*, e.g. color, size, shape, texture, or *extrinsic*, e.g. expressing some evaluative notion such as pretty or dangerous.)

b) *Distinctive marker*. ('Scorpion' is defined in part as having a long tail with a stinger on it, 'centipede' as having many legs.)

c) *Habitat*. ('Burrowing owl' is defined in part as living in holes in the ground.)

d) *Behavior or action*. ('Bee' is defined in part as making honey, 'star' as coming out at night and shining.)

e) Age, sex, line of descent, generation.
(These components are used to define kinship and other status terms.) (1967:168-9)

The distinction between 'intrinsic' stimulus properties like size and shape and 'extrinsic' or evaluative stimulus properties seems rather tenuous. Size requires a value judgment just as beauty does. Both are apparently relative to some expected norm. (For further elaboration on this point, see sections II.2.e and III.5.) The distinctive marker might fit into their tentative part-whole or constituent relation, and habitat might be viewed as a type of locative or provenience. Furthermore, behavior or action bears a very strong resemblance to the relations which Casagrande and Hale call operational and function. As a consequence, classification of all these as attributive may be open to question.

The relation which Casaagrande and Hale call exemplification is the inverse of the attributive relation: "here, the attribute is being defined rather than the possessor of the attribute. Thus in exemplification, 'to hop' is defined in part as 'that which hops' " (1967:181). The elicited definitions of verbs and adjectives fit this description rather closely, e.g. 'Spherical - as a melon'. In addition, one might be tempted to translate some of the noun-noun examples into English as part-whole or inalienable possession:

top knot: '...of a quail'

tail: 'horses have tails' (1967:181)

In Werner and Topper's (1976) most recent schema, modification is a generalized predicate relation which contrasts only with the relations of taxonomy and queuing. All lower level terms in a taxonomy are constructed out of higher level taxons by means of the relation of modification, and many (or possibly all) complex relations are constructed from combinations of the atomic relations of modification, taxonomy, and queuing.

MODIFICATION IN LINGUISTICS

Apresyan, Mel'čuk, and Žolkovsky use the word *attribute* in describing several of their relations. For example, A_i is defined as 'the generic, attribute of the first, second, third,...participant in the situation' (1970:12). A_1 (*to know*) = *aware*; A_2 (*to know*) = *known*, *familiar*. Magn is defined as an attribute denoting 'very', 'to a great extent' (1970:13). Magn(*rain*) = *heavy*. Bon is an attribute meaning 'good'. Bon(*aim*) = *lofty*. These lexical functions seem to express collocation relations rather than the kind of attribution or modification described by Casagrande and Hale. Such collocation relations are very important in practical lexicography. (This problem will be discussed in greater detail in section IV.1). Not all sources agree on how or whether to include these relations in a memory model. Other relations proposed by Apresyan, Mel'čuk, and Žolkovsky seem to conform more closely to the Casagrande and Hale definition of attribution. For example, Son gives the typical sound, Son(dog) = to bark, a kind of auditory-perceptual distinctive marker, and S_{loc} in examples such as S_{loc} (arrow) = quiver, is reminiscent of Casagrande and Hale's habitat.

In his extended model, Mel'čuk hypothesizes the deepest or primary semantic level as composed of predicates, for example: yellow(stove); yellow(color); love(John;Mary); give(x;y;z). Although not explicitly specified, the relationship between predicates and arguments can be seen as one of attribution or modification (Workshop, Northwestern University, 11/21/78).

MODIFICATION IN PSYCHOLOGY

Riegel (1970) uses a whole family of relations to correspond to various subtypes of modification. All of his infralogical relations describe attributes of objects and events. The relation of quality seems to be the most central. Some others are partness, wholeness, location, and substance.

Rumelhart, Lindsay and Norman (1972) distinguish at least three types of modification which they represent in strikingly different ways. Qualities are related to concepts by the IS relation: John IS fat. Properties of concepts are expressed by the HAS relation: animal HAS feet. Adverbial modification, on the other hand, is treated as a kind of relational operator. The relational operator *slowly* operates on the relation *walk* to produce the relation *stroll*.

Modification in Kintsch's model of lexical memory is represented by list entries of a special form. Every lexical entry contains a description list, a list of propositions which describe the entry, joined together by conjunction and disjunction operators. A possible description list for the concept *apple* would be (1972:262-263):

(FRUIT,APPLE) ∧ ((DELICIOUS)TASTE,APPLE) ∧
(((RED)COLOR,APPLE) ∨ ((YELLOW)COLOR,APPLE) ∨
((GREEN)COLOR,APPLE))

In other words, an apple is a fruit, an apple is delicious, and an apple is either red or yellow or green. Description lists for more complex concepts have a correspondingly complex structure. The fact that dust nebulae are illuminated by nearby stars is represented as:

(ILLUMINATE,(NEAR)STARS,(DUST)N2)

As this example shows, this same parenthesized list notation is used to indicate all types of modification.

Quantification (ibid.:275) is also treated this way. One difficulty with this notation is that the relation betwen fruit and apple and the relation between (red)color and apple are represented in precisely the same way.

Collins and Quillian, on the other hand, emphasize the importance of specifying the relation between properties and concepts:

> Worms are related to birds because birds eat them (though they are undoubtedly related in other ways too), and to dogs because worms live in a dog's coat of hair. The particular relation is as important to the property as the concepts that are related. Any memory structure that sloughs over these differences could never deal very intelligently with human language. (1972:315)

Every concept within their system has a property list. Properties on these lists are made up of two parts: relations and objects. For adjectival properties, the relations are called attributes and the objects are called values. For example, the property list for the concept 'red block' will contain the attribute-value pairs: color-red, and shape-square.

MODIFICATION IN COMPUTER SCIENCE

Simmons' (1973) parsing program begins by attaching the label MODification to the arc connecting the noun and its adjective modifier. Then, as the computational process proceeds and more information is collected, the label MOD is replaced by a more specific label such as SIZE, COLOR, SHAPE, etc., which he describes as semantic relations underlying MOD. Both 'the barn is red' and 'the red barn' are ultimately represented by the same structure (see Figure 27).

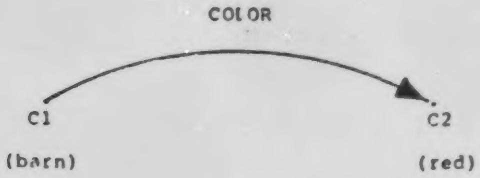


Fig. 27. Modification in Simmons' Model.

Schank uses the symbol $\Longleftrightarrow$ for modification which he treats as a two-way dependency. Wilks (1973) also uses a symbol, not a name, for this relation, but his symbol is a one-way arrow $\longrightarrow$ Winograd (1972) treats modifiers as one-place predicates; (MORTAL : SOCRATES) is his representation for 'Socrates is mortal'. While all three models provide a represention for modification and use it computationally in question-answering, they do not treat it as a full-scale relation in the way that Simmons does.

Simmons treats adverbials in a similar way. For example, slowly and in the morning are initially linked to the verbs and adjectives which they modify by the relation VMOD. Then during the computational process, VMOD is replaced by the more specific relations FREQUENCY, INTENSITY, etc., as appropriate.

ISSUES IN MODIFICATION

TYPE-TOKEN RELATION

The relation between a type and its realized tokens can be considered a form of attribution. Since attribution is one aspect of modification, it can be argued that the type-token relation is a kind of modification. The distinction between type and token occurs in all of the fields we have examined. In text analysis each instance of a word is a token of that word. A paragraph seventy-five words long contains seventy-five tokens. Among these seventy-five tokens, there may be only thirty-two different words or types. The word the, for example, may occur seven times; that is, there are seven tokens of the type the.

Quillian (1968) was the first to include the type-token relation in a model of memory. In his approach the term being defined is a type and any occurrence of that term in a definition of another type is a token. In Werner's model

(1978) the type-token relation is named TTL (type-token link).

The bird taxonomy represented in Figure 28 states that a canary is a yellow bird. The node marked yellow is a token node as indicated by the square brackets. It is linked by the TTL relation to the node yellow in its home taxonomy, the color taxonomy.

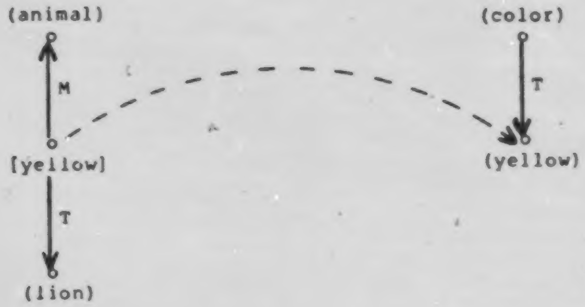


Fig. 28. Type-Token Links in Werner's Model.

Simmons (1973) employs a relation TOK which points from a concept node to the corresponding lexical node. In Rumelhart, Lindsay, and Norman (1972) the DEF relation connects an object to its underlying concept and the ACT relation connects an action to its realization in an event.

Schank does not have a relation of this type. Owing to his conviction that all memory is episodic, his model does not have lexical or generic nodes separate from the particular nodes representing a given piece of text.

These different models reflect a deep philosophical and psychological controversy about the nature of the mental representation of word meaning. To those who, like Schank, believe that all memory is episodic, this mental representation is a collection of memory-records or traces corresponding to occasions when the word has been used. On the other side, we have those who believe, like Quillian, that the mind creates from these occasional uses, a unit, a single generic node, which is stored in semantic memory.

There are intermediate positions held by those who posit differing amounts of mental processing and node creation. In addition, over the course of their work, authors change positions on this issue. For example, in the last ten years, Werner has moved from Schank's position to Quillian's.

SYMBOL MAPPING

Computer scientists are currently concerned with the symbol-mapping problem, which requires efficient exploitation of the connection between modification and taxonomy (Fahlmann 1975; McDermott 1975). An example can best illustrate the problem. If we know that Ernest is an elephant, then the attributes of elephant apply to Ernest. In a computer model, with its limited memory it is important to store these attributes only once. Presumably universal or typical attributes of elephants should be stored under elephant and only Ernest's own special attributes should be contained in the Ernest entry. Since an elephant is a mammal, the attributes of mammal apply to elephant and Ernest as an elephant inherits them. A satisfactory solution of the symbol-mapping problem requires a compact storage organization scheme and retrieval algorithms that make it possible to retrieve swiftly all the relevant taxonomically implied properties.

VARIABILITY

How can we keep a question answering system from inferring that Ernest the elephant is smaller than the alley cat George, when it is told tha Ernest is a small elephant but George is a large cat?

Variability is a critical problem in the analysis of modification. Lyons (1968) and Bierwisch (1969) favor the theory that there are implicit norms associated with adjective-noun combinations. Using this approach Lyons' analysis of the sentence 'A small elephant is a large animal' employs the following reasoning:

> An elephant which is small-rather-than-large by comparison with the norm relevant for elephants is (nevertheless) large-rather- than-small by comparison with the norm relevant for animals. (1968:466)

To Simmons and other computer scientists the problem of variability causes serious practical difficulties for models of question-answering and deductive information retrieval. Simmons emphasizes the importance of context as well as relative norms. For example, in his view, the function of adjectives is to signal a change from the characteristic attribute: 'for example "yellow brick" changes the characteristic reddish color associated with "brick" to the value "yellow"' (1973:75).

Recent research and experimentation in fuzzy set theory (Zadeh 1965; Lakoff 1972; Rosch 1973; Rosch et al. 1975; Smith, Shoben, and Rips 1974) have shown that variability is an important property of noun classes. In such an approach the noun class elephant would contain members ranging in height from four feet to fifteen feet, and varying in color from black to white (or pink).

The recognition of variation within noun classes alone does little to resolve problems of variability raised by Lyons (1968), Bierwisch (1969), and Simmons (1973). Variation must be placed within a total model or structure of the lexicon. In the theory of fuzzy sets the variation inherent in each category relies on the notion of typicality or core meaning.

An approach to variability was proposed by Zadeh (1965) and called fuzzy set theory. Fuzzy set theory attempts to characterize the tendency of classes of objects to have imprecisely determined boundaries. These sets range from those with clearly indeterminate boundaries such as _the class of numbers much greater than ten_ to sets such as _animals_ which have traditionally been viewed as having a limited, well defined membership. In fuzzy set theory membership is graded from zero to one, to account for the transition from nonmembership to membership. Rosch (1973, Rosch et al. 1975), Lakoff (1972), Markowitz (1977), and others expanded Zadeh's theory to include psychological and linguistic information about the intensions of terms which might account for the gradability for extensions that was noted by Zadeh.

The psycholinguistic processes which seem to underlie membership gradation involve the occurrence or co-occurrence of attributes. According to Rosch two of these processes are family resemblance and cue validity. Family resemblance is based on the observation that one can rarely find a set of characteristics which are common to all members of a single category. However, certain attributes, such as wings and feathers, tend to co-occur. Cue validity is a measure of the strength of association between an attribute and the categories associated with it. The more categories associated with a cue, the less strength it has. Because 'has wings' is strongly related to many categories (e.g. insects, birds, and airplanes), it has less cue validity than 'has feathers' for the bird category.

Context is also a factor in fuzzy set membership. Dreyfuss et al. (1975) and Markowitz (1977) note that contextual differences can account for shifts in typicality. Thus 25° F. may be cold anytime for Miami, but not for Chicago in January; and a bomb may be a typical weapon for a battlefield, but not for the streets of Chicago.

Lyons (1968) points out that norms may vary across cultures or between subgroups of a single culture. A typical house in one culture may be very atypical in another culture and a house that is small in Evanston, Illinois, may be considered big in a Navajo community. Norms may also vary idiosyncratically. Stella and Mike may disagree about whether or not Joe is a bad chess player because they have different norms for chess playing ability.

According to Lakoff fuzzy membership gradations can be expressed linguistically using 'hedges'. He writes that hedges are 'words whose job it is to make things fuzzier or less fuzzy' (1972:195). A robin's high typicality rating for the bird category can be expressed linguistically as 'a robin is a bird par excellence'. The chicken, which has a poor rating for bird, is described as 'technically a bird'.

Proponents of fuzzy set theory maintain that membership typicality is not a product of frequency of occurrence. In a comparison of fuzzy membership grades with word frequency counts, Markowitz (1977) found that frequently occurring items were often rated as poor category members. *Shirt*, *jacket*, and *socks*, for example, were generally rated as more typical examples of clothing than the more frequently occurring *hat*. A more accurate measure of typicality can b found in category response norms where subjects are asked t list as many members of a target category as they can in given amount of time.

FORMAL PROPERTIES OF MODIFICATION

The formal properties of the relation of modification can be summarized as follows:

(i) M is reflexive.

In Werner's formulation this is written (a)M[a]. Here (a) indicates a type, while [a] is a token.

(ii) M is not symmetric.

That is, (a)M[b] and (b)M[a] are not equivalent, though they both may be possible as in the contrasting pair canary yellow and yellow canary.

(iii) M is not transitive.

That is, the knowledge that (a)M[b] and (b)M[c] tells us nothing in general about whether (a)M[c] is true or not. For example, we cannot infer from the fact that yellow modifies canary, (yellow) M [canary], and that canary modifies cage, (canary) M [cage], that yellow modifies cage. The canary is yellow, but the cage may be yellow, blue, green, or black.

3 SYNONYMY

The concept of synonymy has played a central role in both dictionary-making and linguistic theory for many years.

SYNONYMY IN ANTHROPOLOGY

In collecting folk definitions Casagrande and Hale (1967) classified as synonymous those in which 'X is defined as being equivalent to Y'. Their examples include nouns, verbs, and adjectives: amusing - funny, hunchback - camel, new - modern, to wake someone up - to get someone up. Some examples come from different dialects; some from the same dialect.

Werner takes the same intensional/extensional perspective on synonymy as on taxonomy. At one point he treated synonymy as a separate relation which he defined as 'the identity of intensions and extensions' (1972b:15). As we have seen (in section 1.e.iii of this chapter), when (a)T(b), then the extensions of (a) and (b) are related in one direction and the intensions in the other:

$$\text{extensions (a)} \subset \text{extensions (b)}$$
$$\text{intensions (a)} \supset \text{intensions (b)}.$$

As Werner has pointed out, synonymy can be viewed as the limiting case of taxonomy, the case where set equality holds for both extensions and intensions. In his current model, therefore, he defines synonymy in terms of taxonomy. (a) and (b) are synonymous when both (a) T (b) and (b) T (a).

SYNONYMY IN LINGUISTICS

Apresyan, Mel'čuk and Žolkovsky have attempted to state a more precise criterion for synonymy: the two words should be semantically substitutable for each other, and the meaning of one should be expressible through the other in any context (1970:5). They list synonymy as their first function with these examples: Syn(to help) = to aid; Syn (to call) = to name. A literary form of synonymy is expressed by their Figur relation which points to the standard figurative designation. Figur(passion) = flame; Figur(misery) = abyss.

Lyons developed the idea of mutual substitutability into an elaborate linguistic methodology. It requires five steps (adapted from Lyons 1963:74-78):

1. Take two candidate sentences differing in one element.
2. Make sure the contexts of both are identical.
3. Get informant judgment of sameness of meaning of the items by which target sentences differ.
4. Place these two items in a variety of sentences.
5. Get informant judgments on sameness of meaning in all sentences.

A test of this sort implicitly assumes that there is only one type of synonymy. Not all theorists agree with this view.

Palmer (1976:60-64) distinguishes five different types of synonymy. First, synonyms may originate in different dialects, e.g. fall and autumn. Secondly, some synonyms are appropriate to different registers or roles. His examples are: *a* nasty smell, an obnoxious effluvium, and an 'orrible stink. Thirdly, some words have the same cognitive meaning but different emotive or evaluative meanings, e.g. thrifty, economical, stingy. Fourthly, he claims, some choices between syononyms are collocationally determined: butter is rancid, but eggs are addled. Lastly, we have partial synonyms which overlap in meaning like govern, direct, and control.

Synonymy is a central concept of transformational grammar. Different schools of transformational grammar disagree about what sentences are or are not synonymous. Without synonymy, of course, the whole notion of transformation of sentences and meaning preservation becomes untenable.

SYNONYMY IN PSYCHOLOGY

Many standardized tests constructed by psychologists to measure intelligence (e.g. Weschler Tests, Binet) or achievement (e.g. Woodcock Reading Mastery - word comprehension subtest) either explicitly or implicitly use synonymy as a scoring category. Synonymy has been viewed as relating word pairs on word association tests (Deese, 1965); Miller lists 'similar' as the relationship of blossom to flower, pain to hurt, swift to fast (1951:179).

Of the psychologists on whom we are focusing, Riegel (1970) and Kintsch (1972) both list synonymy as the first semantic relation. Riegel also identifies some word association data as examples of synonymy, but does not state his criteria.

The appeal to synonymy by psychologists has been largely intuitive rather than theoretically motivated. It has not been considered until recently that synonymy (appearing in literature since ancient times) could be of questionable importance. Miller and Johnson-Laird credit Lyons (1963) with observing that 'the relation of synonymy, which has received so much attention from writers on semantics, is far less important' (1976:266). Like Werner (1972a), Miller and Johnson-Laird emphasize the greater importance of 'hierarchical field properties' (taxonomy) and 'contrastive field properties' (contrast sets, set membership, grading, and modification). They add: 'One can conceive of a language that would make no use of synonymy; it is hard to imagine how a language in which contrastive and hierarchical field properties played no part could function at all' (ibid.:266).

SYNONYMY IN COMPUTER SCIENCE

Rather than using the term synonymy, computer scientists talk primarily about equivalence relations and equal sets, using an entirely extensional approach. Simmons (1973) lists EQ as a set relation and indicates that it joins lexical nodes. He seems to be defining concepts extensionally. Term1 EQ Term2, applies, if the sets of objects they name are equal. His relations IMPLY and IMPLYBY also indicate a kind of synonymy: the relationship (Napoleon IMPLY Bonaparte) allows us to substitute Bonaparte for Napoleon.

Raphael's (1968) Semantic Information Retrieval program, an early experiment in question-answering, is based on a calculus of semantic relations. He calls the synonymy relation EQUIV (for equivalent) and defines it: 'X and Y name the same object'. He points out that EQUIV is symmetric as well as transitive and uses this symmetry in his deductive system. The question-answering system designed by Stephen Marx (1972) uses lexical functions called synonym and inclusion (taxonomy) in problem-solving.

ISSUES IN SYNONYMY

EXISTENCE

Does synonymy really exist? Do two words ever have the same meaning or are there always differences? Our sources disagree vehemently. Practical lexicographers use synonymy constantly. (See the American Heritage Dictionary 1969 and Webster's New Collegiate Dictionary 1951, among others.) Most computer science models assume that there may be two names for one object or concept, although they are more likely to call this relation equality or equivalence than synonymy. For Apresyan, Mel'čuk, and Žolkovsky (1970) synonymy is first not only in position but in importance, partly because it serves as an essential basis for paraphrase. Among psychologists Kintsch states that, 'the most common semantic relationship used in definitions is synonymy' (1972:250).

Anthropological fieldwork does not apparently support the centrality of synonymy. Casagrande and Hale (1967) found it only ninth in order of frequency of occurrence among thirteen relations. Werner and Toppper (1976) include S (synonymy) in their list of relations, but treat it as a limiting case of taxonomy occuring when both (a) T (b) and (b) T (a). For example: help is a kind of aid; aid is a kind of help. Help and aid are linked taxonomically in both directions and are thus in some sense synonymous. Lyons (1977) takes a similar stand, viewing synonymy as a kind of symmetrical taxonomy.

Riegel classifies some word association data as examples of synonymy but expresses philosophical doubts about the concept based on the fact 'that perfect synonymity does not exist in the language but that there are always more or less marked deviations in meaning between any two items' (1970:373). Riegel expresses doubts about synonymy, but there is no room at all for synonymy in some theories, e.g. Chafe (1971). Clearly the relation of synonymy poses some troublesome philosophical and procedural problems.

PARAPHRASE

The question of synonymy between lexical items is closely connected to the problem of paraphrase, or synonymy between sentences and paragraphs. When, if ever, do two sentences have the same meaning? One can argue, as in Chafe (1971), that different forms exist precisely in order to allow us to express difference in meaning.

Žolkovsky and Mel'čuk (1970) represent the opposite extreme. For them paraphrase is the basis of their theory of semantic synthesis; their goal is the generation of all possible paraphrases from a given sentence of Basic Russian. Simmons agrees emphatically with this point of view and clarifies the criterion of sameness, as follows:

> The following two sentences would usually be judged to carry the same meaning; particularly, if one is a question, the other would be selected as an answer.

1. Wellington defeated Napoleon at the Battle of Waterloo.
2. Bonaparte lost the Battle of Waterloo to the Duke of Wellington.

He amplifies this in a footnote where he places meaning in a pragmatic framework: "'same' is taken to mean 'equivalent with respect to a purpose'" (1973:99). His purpose is presumably retrieving a satisfactory answer to a question.

Paraphrase has also played an important role as a basis for argumentation in Transformational Grammar. One goal of the Katz and Fodor (1963) semantic feature model was to explain synonymy and paraphrase. It has been important in Generative Semantics too, as in McCawley's (1970) analysis of kill as cause-to-become-not-alive. Most of these discussions of synonymy and paraphrase are rooted in syntactic data. They are based on examples in which two terms have equivalent syntactic features or equivalent syntactic derivations.

Whatever the philosophical or procedural difficulties, synonymy is too ubiquitous to be ignored. One possible reason for this is that, like taxonomy, synonymy has formal properties which make it important in deductive processes.

FORMAL PROPERTIES OF SYNONYMY

In most computer models synonymy is treated as an equivalence relation; that is, it is assumed to be reflexive, symmetric, and transitive. Letting S stand for synonymy, we see that S is

(i) reflexive: (a) S (a) for all (a) or, in other words, any concept or node has the same meaning as itself.

(ii) symmetric: if (a) S (b), then (b) S (a) for all (a) and (b); that is, if (a) has the same meaning as (b), then (b) has the same meaning as (a).

(iii) transitive: if (a) S (b) and (b) S (c), then (a) S (c). If (a) and (b) are synonyms and so are (b) and (c), then (a) and (c) are also synonyms.

When we consider words in isolation, statements (i)-(iii) seem entirely valid. However, context can sometimes cause difficulties. Ancestor and forefather are often listed as synonyms. In Lyons' appproach to synonymy, for example, (ii) would say that if ancestor is substitutable for forefather then forefather is substitutable for ancestor. In fact ancestor can be substituted for forefather in most contexts but it is awkward to substitute forefather for ancestor in a sentence like 'Abigail Adams is an ancestor of mine'.

CONNECTION BETWEEN SYNONYMY AND OTHER RELATIONS

Synonymy is closely connected with both taxonomy (see section 1.g of this chapter) and antonymy. The interaction between synonymy and antonymy has been used by Palmer (1976) to explore polysemy. The computer scientists Edmundson and Epstein have also explored polysemy, using synonymy as a tool.

Edmundson and Epstein (1969,1972) have developed a mathematical model of synonymy and antonymy. They have developed a computer representation of their model and tested it on Webster's New Dictionary of Synonyms (1968). Using algorithms adapted from graph theory, they can test whether their axioms hold for a given set of dictionary entries. They can also build new properties out of primitives and test for them in any subset of the data base. Their definition/test for polysemy uses their computer model to find sets of mutually synonymous words. Synonymy is generally transitive: If it is known that foolish is synonymous with silly and silly with fatuous, then it may be assumed that foolish and fatuous are also synonymous. When transitivity breaks down, there is reason to suspect polysemy. The dictionary lists as synonyms for simple both effortless and silly, but does not include effortless listed as a synonym of silly. This is evidence of the polysemy of simple. In fact Edmundson and Epstein's (1972) program identifies five distinct senses for simple:

Sense No.	Synonyms
1	pure, absolute, sheer
2	easy, facile, light, effortless, smooth
3	plain, homely, unpretentious
4	natural, ingenuous, naive, unsophisticated, artless
5	simple, foolish, silly, fatuous, asinine (1972:4)

Palmer has suggested using antonymy as well as synonymy in the task of discriminating between multiple senses of a polysemic word. The adjective fair has distinct opposites in different contexts (1976:69-70).

Context		Antonym
fair hair	-	dark hair
fair skin	-	dark skin
fair weather	-	foul weather
fair sky	-	cloudy sky
fair judgment	-	unfair judgment
fair tackle	-	foul tackle

A change in antonym provides evidence of a change in meaning.

4 ANTONYMY

Antonymy is one of the most commonly cited lexical-semantic relations. Traditionally it, like synonymy, has been a focus of philosophical linguistic investigations. Ogden (1967[1932]:21-55) gives an interesting historical overview of opposition beginning with the Pythagoreans' ten fundamental oppositions in the universe and Aristotole's development of classical logic. He comments in particular on those aspects of opposition which have most interested logicians: contradictories, contraries, privative terms, repugnant terms, and relative terms. Webster's New Collegiate Dictionary (7th edition, 1951) lists antonyms as well as synonyms. For example the definition of cold includes 'Ant. hot'. (The definition of hot although it mentions cold does not include 'Ant. cold'.) Webster's defines antonym as 'a word so opposed in meaning to another word that it negates or nullifies every single one of its implications'. As we shall see, for most authors this definition is too strong. For many there is more than one kind of opposition of meaning.

ANTONYMY IN ANTHROPOLOGY

Casagrande and Hale (1967) have a single antonymy relation, tenth in frequency of occurrence in their Papago folk defintions. It appears whenever *x* is defined as being 'the negation of y, its opposite.' All their examples contain 'not', e.g., 'low...not high.' Werner (1978) does not use a special antonymy relation at all. He expresses opposition by using the logical relation 'not' or simply N.

ANTONYMY IN LINGUISTICS

Apresyan, Mel'čuk, and Žolkovsky (1970) have two lexical functions which express opposition: Anti (antonym) and Conv (conversive). The examples given for Anti all involve lexical opposites:

Anti(beautiful) = ugly
Anti(friend) = enemy
Anti(to love) = to hate
Anti(before) = after

Their other opposition function, Conv, covers grammatical opposites instead (1970:9):

> A typical example of the converse term is the passive voice of the verb. In general, only such words have conversives as denote a situation with more than one participant.
>
> Conv(to build) = to be built

Besides passives (and pseudopassives), they include the following syntactic examples which express lexical opposition.

A precedes B = B follows A

A has won over B = B has lost to A

A sold B to C = C bought B from A

The earth seeps in = the moisture penetrates
[better 'soaks up' into the earth (1970:9)
or 'drinks up']
the moisture

Conv generally denotes 'a situation with more than one participant' in which the role of the participant changes, whereas this is not relevant to Anti. Each Conv entry is accompanied by a list of transformations which describe the permutations of the syntactic arguments. Fillmore (1972) classifies lexical items such as open and shut/close, and come and go as deictic verbs and describes the alternation of participants in terms of case and deixis.

Lyons (1968) has identified three different kinds of oppositeness: complementarity, antonymy, and converseness. Complementarity covers terms like single and married or male and female where the assertion of one implies the denial of the other and also the denial of one implies the assertion of the other. This is an either/or relation: everyone to whom the term applies is either male or female. Complementarity holds primarily between two adjectives or two adverbs.

Lyons' (1968) antonymy relation covers those sets of terms where the assertion of one implies the denial of the other, but the denial of one does not imply the assertion of the other. *Hot* and *cold* are antonyms since, if X is hot, it is not cold, but, if X is not hot, one cannot conclude that it is cold; it could be tepid or cool. Sets of terms such as *red*/*green*, *good*/*bad*, *light*/*heavy*, *big*/*small*, *short*/*long*, *far*/*near*, *frequent*/*rare* behave similarly. Many of these adjectives which imply grading cause special problems. The assertion, 'a small elephant is a large animal', can be viewed as a problem involving gradable adjectives. As we have seen in our examination of modification, however, problems of this sort involve an implicit norm rather than a simple, undifferentiated scale of values.

Lyons' (1968) third kind of oppositeness, converseness, covers such examples as *buy* - *sell*, *offer* - *accept*, and *husband* *of* - *wife* *of*. It does not involve negation at all but a permutation of associated individuals. Dale (1972:44) refers to this relation as 'reciprocity'. As we have seen, Apresyan, Mel'čuk, and Žolkovsky (1970) use 'conversive' for *buy* - *sell* and handle the deictic quality of these terms by prescribing transformations which switch arguments.

Palmer (1976:82) has pointed out that some of Lyons' examples, while they are reciprocal, do not involve the strong entailment of *buy* - *sell*; e.g., *offer* does not imply *accept*. Such examples as *ask* - *reply*, like *offer* - *accept*, really express a temporal relationship, he claims (ibid.:84). Leech (1969, 1974) divides antonymy into polar/binary opposites and relational opposites; the latter are comparable to Lyons' gradable antonyms. Gruber (1965:29-42) has a reciprocal relation as well as an antonymic (=counterpart) relation. For example:

reciprocal: buy-sell, give-obtain, loan-borrow
antonymic: inside-around, above-below,
after-before

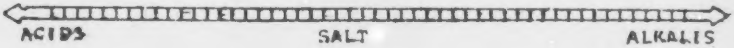
ANTONYMY IN PSYCHOLOGY

Opposition also appears as a category on standardized tests (e.g., Illinois Test of Psycholinguistic Abilities: 'A rabbit is *fast*; a turtle is *slow*.') and in word-association pairs (e.g., *light-dark*, *war-peace*). Opposites have been used in both free and controlled association tasks; and especially with words of frequent usage, opposites are one class of words that manifest the shortest reaction times on associational tests. Psychologists have not, however, examined the varying nature of oppositeness more closely, but rather tend to view antonymy as a unitary and intuitively obvious relationship between pairs of words.

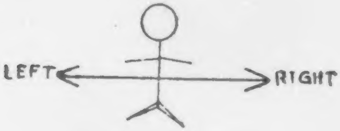
Riegel (1970) has a simple antonymic relation which represents 'contrast': 'x is not a y'. He classifies this relation as a logical relation, one of the group derived by verbal abstractions rather than by perceptual/physical features. The kind of opposition expressed by before-after he places on a higher level; these are meta-relations for Riegel.

Many of the difficulties inherent in opposition have been exhaustively explored by Ogden (1967[1932]). He divides opposition into: terms opposed by negation, by definition, by fictional opposition and by directional opposition (ibid.:104). His opposition by negation is similar to Casagrande and Hale's (1967) antonymy and is effected by adding a negative, e.g. visible - invisible. His opposition by definition is similar to Lyons' complementarity, e.g., male - female, town - country, love - hate. Included in this group are reciprocals like ruler - ruled, uncle - nephew/niece, which Ogden calls 'correlatives'. His fictional oppositions include liberty - slavery, beauty - ugliness. The most interesting opposition for a discussion of gradability or variability is his notion of directional opposition, which presupposes two underlying configurations: the scale and the cut.

Ogden argues that many opposites are actually 'two extremes of a scale or two sides of a cut; the cut marking the point of neutrality, the absence of either of two opposed characters in the field of opposition' (1932/1967:58-9). Scalar opposition permits values along a continuous dimension, which can form a series. Furthermore, two series can be placed end-to-end, as in the scale of acids as far as the neutral dividing line (salt) with a similar scale of alkalis on the other side.



Cuts, on the other hand, involve distance from a middle point (often originally, the body), for example, positive and negative numbers are 'cut' at zero; one's left and right are 'cut' at one's body.



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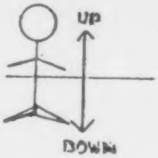

Directional opposites superimpose a particular direction to a scale or cut. Relativistic spatial terms like *further to the left* or *more right* or *up* - *down*, as well as *hot* - *cold*, *alkali* - *acid*, imply either a relative position in a series in the direction of one extreme or the other, or direction from some central cut. Often the separated values on a scale are perceived as opposites because all the values contrast with each other, forming contrast sets, e.g. colors. Similarly, the two directions of a cut can be mistakenly viewed as opposites since they contrast as well (the middle values having dropped out). These latter end points or most typical values seem to Ogden closer to true opposites than scalar opposites.

ANTONYMY IN COMPUTER SCIENCE

Computer scientists have developed radically different models of antonymy. Inspired by the classical approach, Edmundson (1965:5) has divided antonymy into seven subcategories. The first three come from classical logic.

contradictory	(opposed in meaning so that one is the negation of the other: *perfect*-*imperfect*)
contrary	(opposed in meaning so that both cannot be true: *superiority*-*inferiority*)
relative	(opposed in meaning so that one is inverse or converse of the the other: *parent*-*child*)

complementary	(opposed in meaning so that one is reciprocal to the other, i.e., one is incomplete unless the other follows: *attack*-*defend*)
reverse	(opposed in meaning so that one reverses or undoes the quality, act, or state of the other: *destructive*-*constructive*)
contrasted	(opposed in meaning so that one presents a sharp contrast to the other: *dry*-*moist*)
incompatible	(opposed in meaning so that they differ only in a small part of their meaning, i.e. they usually cannot simultaneously be applied to the same thing: *abstruse-superficial*)

Evens' (1975) model, inspired by Lyons (1968), uses his complementarity and antonymy relations, but splits converseness into CONV (converseness proper: *buy* - *sell*) and RECK (RECiprocal Kinship and social terms, *parent* - *child* and *student* - *teacher*) in order to take advantage of somewhat different deductive patterns. Simmons (1973) has no antonymy relation at all. He uses NOT or NEG to express opposition.

ISSUES IN ANTONYMY

CONTRAST SETS

The question raised by sets of incompatible terms, especially color terms, is treated by Kay (1971). Kay discusses 'contrast sets', identifying several kinds of such sets depending upon the structure of the taxonomies of which they are a part. There can be four types of contrast:

(1) Inclusion contrast which obtains between members of a taxonomy on two levels; one node dominates the other. In Figure 29, t_1 and t_2 would show the inclusion of red (t_2) in color (t_1).

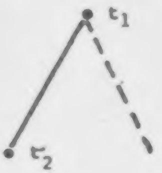

Fig. 29. Inclusion Contrast

On the same level of a taxonomy, three types of contrast exist.

(2) Direct contrast which obtains between members on the same level of a taxonomy dominated by the same node. In Figure 30, t_4 and t_5 would show the direct contrast of colors, red (t_4) and green (t_5).

(3) Indirect contrast which obtains between members of a

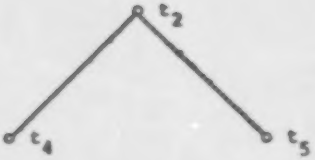

Fig. 30. Direct Contrast.

taxonomy dominated by two different nodes. In Figure 31, t_4 and t_6 would show indirect contrast such as ruby red (t_4) and lime green (t_6), but would also illustrate contrasts between levels such as ruby red (t_4) and green (t_3).

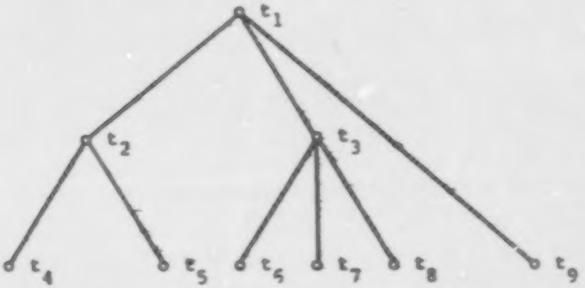

Fig. 31. Indirect Contrast.

(4) Terminal contrast which obtains between any members at the lowest level of taxonomy. In Figure 31, t_4 terminally contrasts with t_9 and t_4 terminally contrasts with t_5. The contrast of t_4 and t_5 is also a subtype of direct contrast while the terminal contrast t_4 with t_9 is a

subtype of indirect contrast. Examples of terminal contrast are *ruby red* (t_4) with *scarlet red* (t_5) and *ruby red* (t_4) with *brown* (t_9).

Therefore, members of a taxonomy are either in a relation of strict inclusion (Figure 29) or mutually exclusive (Figures 30 and 31). Kay's (1971) conception has the advantage of identifying specific types of mutual exclusion covered by most authors as antonymy or varieties of antonymy.

Werner (1969, 1978) does not use an antonymic relation, preferring, like Kay (1971) to visualize semantic contrast through taxonomic structures. He uses a negative relation which can create oppositions by simple negation. It should be noted that color terms can be related by direct or by indirect contrast, depending upon the taxonomic structure of the set of terms. Furthermore, if color terms are organized according to the spectrum, on a scale from the greatest absorption of rays to the least, a grading or queuing relation can also convey the relationship between terms. (See *yellow* - sort of white, Casagrande and Hale 1967, in the section on grading, section 5 of this chapter.)

In a recent article Kay and McDaniel (1978) take a similar approach to the organization of color terms. They use fuzzy set membership to express the continuous grading of color terms ranging from nonmember (0) to excellent member (1). According to them the gradations correspond to neurophysiological responses of the cone cells in the retina of the eye. They identify four basic categories of neural response: red, green, yellow, blue. Using this approach a nonbasic color such as orange can be described as being a member of red and of yellow to 0.5 degree. While Kay and McDaniel's research is an excellent source of support for fuzzy set analysis, it is more applicable to physiologically measurable phenomena (e.g. color, temperature) than to other concepts. In this view antonymy is not one simple relation but an interaction between taxonomy and grading.

LEXICAL VS. SEMANTIC RELATIONS

Kay's analysis raises the issue of the difference between lexical and semantic relations. In particular, are members in terminal contrast always lexemes while superordinate taxa may be 'lexically unmarked' (1971:874)? If so, are lexical relations those which always deal with lexemes while semantic relations deal with higher-order 'sememes', which may or may not be lexically realized or even realizable? (This may be seen as a ramification of the controversy about 'covert' and 'overt' nodes.) Then, might there be lexical contrast or oppositeness as well as semantic contrast or oppositeness, and could this fact account for the varieties of and confusion surrounding the relation of antonymy? It does seem to be the case that authors who deal with semantic relations are concerned about the placement of terms in larger networks (e.g. taxonomies) while those who deal with lexical relations focus on contrasts and collocations of specific lexical items.

SEMANTIC FEATURE MODELS

In a semantic-syntactic feature model which specifies lexical items through bundles of binary semantic-syntactic primes, e.g. Katz and Fodor (1963), synonymy and antonymy are easy to define. Synonymy becomes identity of features and antonymy becomes the difference between a plus or minus value of a given feature. From the perspective of a network or relational semantic model, it is doubtful that antonymy can be dealt with so simply.

FORMAL PROPERTIES OF ANTONYMY

All forms of antonymy seem to be symmetric. If (a) is opposed to (b) then (b) is opposed to (a). If the relation of opposition is denoted by A, then:

(i) Antonymy is irreflexive.

For all (a), not ((a) A (a)).

(ii) Antonymy is symmetric.

For all (a), (b), if (a) A (b) then (b) A (a).

(iii) Antonymy viewed as a whole is not transitive. The variety which Lyons (1968) labels complementarity seems to be intransitive, that is, if (a) A (b) and (b) A (c), then not ((a) A (c)). The relation which Lyons terms antonymy proper may be transitive, if it is restricted to contrast sets. If (a) A (b) means that (a) and (b) are distinct members of the same contrast set containing more than two members, then for distinct (a), (b), (c), if (a) A (b) and (b) A (c) then (a) A (c). Converseness seems to be neither transitive nor intransitive. For example, (mother) A (father), (father) A (child), and (mother) A (child). On the other hand, (buy) A (sell), (sell) A (give), but, in our judgment, it is not true that ((buy) A (give)).

The distinct varieties of opposition have other properties useful in deduction. As Lyons points out, if (a) and (b) are complements like male and female, we know that if a(x) then not b(x) and also if not a(x) then b(x), at least for x that can appropriately be called male or female. If a and b behave like red and green, then we have less information, but we still know that if a(x) then not b(x).

With converseness there are more subtle kinds of implications. For some examples, where a and b are converse, a(x,y) implies b(y,x). With the pair husband-wife, husband(x,y) implies wife(y,x).

CONNECTION BETWEEN ANTONYMY AND OTHER RELATIONS

Under antonymy we have chosen to deal with many gradable or scalable adjectives (and adverbs) such as red - green, hot - cold, black - white, long - short, which may seem to imply the grading relation (cf. section 5 of this chapter) We have tried to show that these lexical items can be approached conceptually as points along a continuous dimension with emphasis either on the continuum (scale and cut in Ogden 1967[1932]) or on the points (contrast sets in Kay 1971). The former or scalar aspects of these terms could be discussed equally well under grading, but we have chosen not to separate this viewpoint from its alternate. We feel this choice is justified since scalar terms are usually dealt with by single lexical items - either as end points or as typical points on a scale. Thus antonymy can be viewed as a separate relation or as a subrelation of grading.

5 GRADING

The term grading is, as far as we know, of fairly recent origin. Apparently, it only became current after Sapir's (1958) paper on the subject.

Grading is the term that we use to encompass a variety of relations used by different authors to refer to linear, ordered, or scalar continua. Some authors' goals are to characterize concepts while others describe physical (e.g. spatial or temporal) phenomena. It is often difficult, therefore, to compare this relation across authors.

GRADING IN ANTHROPOLOGY

Casagrande and Hale (1967) classify as examples of grading those 'where x is defined with respect to its placement in a series or spectrum that includes y'. The definition which they elicited for Monday is 'the one following Sunday'. Werner and Topper (1976) classify this definition as queuing (Q). Casagrande and Hale also classify under grading the example, yellow: 'when something is sort of white but not very white'. There seems to be some overlap here between grading and the comparison relation where x is defined in terms of its similarity or contrast with y, usually involving terms on the same level of a taxonomy. Another Casagrande and Hale relation, contingency, includes those aspects of grading which have a causal or a temporal connotation. Contingency is described: 'x is defined with relation to a usual or necessary antecedent or consequence of y', to lightning: 'when it rains, it lightnings'. Perhaps the relations of coordinate pairs and sequential responses identified by Casagrande and Hale in word-association data also express aspects of grading.

Lehrer has made an extensive study of grading and identified several species. Some series are made up of scales with prescribed intervals; others are derived from hierarchies. 'Overlapping segments' like second, minute, hour, day, week, month, year, decade, etc. are series in which 'each segment is included in the next' (1974b:29) In 'rank sets' like private, sergeant, lieutenant,... 'the terms are incompatible...; however, rank sets are similar to scales in that the items belong in a certain order' (ibid.).

GRADING IN LINGUISTICS

Several of the Apresyan, Mel'čuk, and Žolkovsky (1970) relations, such as Incep-Fin and Caus-Liqu, seem to lie in this area. As we have seen, Lyons' (1968) dissection of antonymy bears strongly on problems of grading. Perhaps his discussion of consequences is also relevant. Maxwell (1974) uses the term contiguity. His examples suggest a well-defined ordering; *six* comes before *seven*; *seven* comes after *six*; *lightning* comes after *rain*.

GRADING IN PSYCHOLOGY

Riegel (1970) has looked at graded time-relations like those connecting preceding, succeeding, and contemporaneous events, but grading is not a central issue for him.

Rumelhart, Lindsay and Norman (1972) use the THEN-relation to link succeeding events, while the TIME-relation connects actions to their time setting. Collins and Quillian (1972) use precedence and consequence to link events, but both these relations seem to express cause and effect as well as time relationships.

GRADING IN COMPUTER SCIENCE

Simmons (1973) is clearly concerned with problems of grading. His greatest interest seems to be in problems of time-grading, and he outlines algorithms for handling some of them in his paper on paragraph generation (Simmons and Slocum 1972).

Raphael (1968) experimented with the grading relations to-the-right-of and just-to-the-right-of in his SIR question-answering system. His relational calculus contains axioms for both relations and the interaction between them. Winograd's (1972) SHRDLU can discuss both time-relations like before, after, and during, and space-relations like on-top-of and supported-by.

ISSUES IN GRADING

UNDERLYING CONTINUUM

What is the underlying continuum: numerical, spatial, temporal, or causal? Our sources do not agree on which are graded and which are not. There is disagreement, as well, about whether the same grading relation can be used on different continua. Werner (1978) uses Q for numerical, temporal, and spatial grading, but treats cause as a complex relation.

How is the underlying continuum organized? There are two aspects of serial organization corresponding to cardination and ordination. (Cardinal numbers are the numbers 1,2,3,... while fist, second, third,... are ordinal numbers.) Piaget (1964) refers to this distinction developmentally as the difference between counting and the concept of number. The first is learned earlier than the second. Piaget's analyses of the cognitive operations involved may prove useful in disambiguating the lexical-semantic structures (Piaget and Inhelder 1969). Series with prescribed intervals (the cardinal series) include numbers, days of the week, and Lehrer's (1974b) overlapping segments. Ordinal series include rank sets and scales derived from hierarchies. Perhaps Casagrande and

Hale's (1967) comparison belongs here too. The notion of taxonomic level seems to be crucial in distinguishing comparison from rank. Colors may represent contrast sets at the same taxonomic level and thus may be related by comparison (Berlin and Kay 1969). They may also be ordered by wave length, for instance, as in a prism, and thus be related by rank. Ranks are sets defined by their ordering which may or may not be on the same taxonomic level or in direct contrast (Kay 1971:877).

EXTENSION BEYOND WORDS AND CONCEPTS

Different parts of a plan or narrative are ordinally organized, either overtly, as in 'first... then...' or covertly, as in steps in a recipe and chapters in a story. Werner and Topper (1976) extend their grading relation Q to include plans and narratives. Simmons and Slocum (1972) assign times t_1, t_2, t_3, etc. to mark successive elements in a narrative text. In contrast Kintsch, Rumelhart, J. Mandler, and others use a series of text relations (cf. III.6).

QUANTIFICATION OF GRADING

Sapir extended the notion of grading to all parts of speech, joining it to quantification and comparison. Every

> quantifiable... (whether Noun,Verb, Adjective, or Adverb), is intrinsically gradable, since no two of anything are really ever equal, only equal in a given context (i.e. for a given purpose, on a given scale) (1958:123).

He distinguished explicit grading from implicit grading. While implicit grading is of little importance logically, it is of considerable importance psychologically, and most important linguistically. The following four types are differentiated:

(1) implicitly gradable but ungraded

ex: house : houses

(2) implicitly graded by quantification

ex: half of a house : ten houses

(3) quantified by implicit grading

ex: much of the house : a large house

(4) explicitly graded and implicitly quantified

ex: more of a house : a larger house

(1958:133-134)

Properties of grading include: symmetrically reversible (far-near); partially reversible (good-bad); irreversible (brilliant-stupid). That is, if x is far, it is not near; if x is good, it is not bad but if it is not bad, it is not necessarily good; if x is brilliant, he is not necessarily less stupid than y and if x is less stupid, he is not necessarily more brilliant than y. Sapir's terminology differs from many of the authors we have considered but it is obvious that he attempted to deal with the same issues. (A full discussion of Sapir's classifications would demand the inclusion of quantification.) We mention these different approaches to illustrate the heavy interplay, alluded to throughout this section, between antonymy and grading.

FORMAL PROPERTIES OF GRADING

Grading or queuing is not reflexive or symmetric. While some types of grading are transitive others are not. To be more precise:

> (i) Grading or queuing is never reflexive, i.e., for all (a), not ((a) Q (a)).
>
> (ii) Grading is not symmetric.
>
> For example, (1979) Q (1980), but not((1980) Q (1979)).

Examination of the question of transitivity, however, discloses that still another distinction is needed. In one kind of grading (a) precedes (b) in a scale or series. In the other, which applies only to discrete scales, the relation holds only when (a) immediately precedes (b). Raphael's (1968) two relations, to-the-right-of and just-to-the-right-of, are examples of this distinction. Werner (1978:52) calls these two types of grading distal queuing Q_d and proximal queuing Q_p. If we look at the integers, for example, the less-than relation is a distal queuing relation while the successor relation that links each integer n and n + 1 is a proximal queuing relation. Distal queuing is transitive while proximal queuing is not transitive.

(iii) Q_d is transitive.

i.e., for all (a), (b), (c), if (a) Q_d (b) and (b) Q_d (c), then (a) Q_d (c).

(iii') Q_p is not transitive. What is more, for all (a), (b), (c), if (a) Q_p (b) and (b) Q_p (c), then not((a) Q_p (c)).

To put this into words, January Q_p February and February Q_p March, but not January Q_p March. If two nodes (a) and (b) are proximally related then they are also distally related but not vice versa.

For all (a), (b), if (a)Q_p(b), then (a)Q_d(b).

Although proximal queuing is not transitive, it has another interesting property which Raphael (1968) terms unique linkage. Each integer has exactly one predecessor and one successor. If (a) immediately precedes (b), then no other object in the same series can immediately precede (b) and, what is more, no object in the series other than (b) can be an immediate successor of (a). In formal terms,

If (a) Q_p (b), then there is no (c) distinct from (a) and (b) in the same series with (c) Q_p (b) or (a) Q_p (c).

In other words, proximal queuing is what mathematicians call a one-to-one relation. Distal queuing is a strong ordering relation in mathematical terms.

CONNECTION BETWEEN GRADING AND OTHER RELATIONS

Grading interacts strongly with both taxonomy and antonymy. Often serially graded items appear in the same level of a taxonomy. The notion of taxonomic level is fundamental to any attempt to distinguish Casagrande and Hale's (1967) grading and comparison from Lehrer's (1974b) rank. Some kinds of antonymy or opposition seem to be best explained, as we have seen, by viewing opposed items as marks on a graded continuum. Antonymy thus interacts with the facet of grading which covers scalar dimensions or ranks.

Still a third aspect of grading ties it to the surface order of sentential syntax more directly. Here we are looking at serial collocation in surface syntax rather than at the more abstract series membership expressed by Werner's (1978) queuing or Casagrande and Hale's (1967) grading. Into this group fall Jakobson's contiguity (1956) and Bolinger's (1975) typical subjects and objects. Casagrande and Hale's (1967) functional, spatial, and operational relations seem to share this aspect of grading, as do the coordinate pairs and sequential responses they identify in word-association data. This kind of series also turns up in Riegel's (1970) experiments. There is an overlap between these relations and syntagmatic category relations and favored case relations.

This concludes our treatment of the major relations: taxonomy, modification, synonymy, antonymy, and grading. We now turn to several additional relations which merit examination.

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CHAPTER 3

OTHER RELATIONS

In this chapter we discuss briefly some other relations which we feel merit examination. We begin with the part-whole relation which is particularly mysterious and intriguing. Then we consider cause, space and location, and provenience or source. We take a look at some of the rich collection of relations provided by Apresyan, Mel'čuk, and Žolkovsky. Finally we give a brief introduction to the new and exciting field of text relations.

1 PART-WHOLE

Casagrande and Hale (1967) call this relation the constituent relation and describe it in the words: 'X is defined as being a constituent or part of Y'. They did not find this relation in their Papago sample, perhaps because many concepts which are ordinarily defined by a part-whole relation in English, like body parts, are apparently defined by the spatial relation in Papago (tongue: '...which stands in our mouth.' ncse; 'it stands below our eyes.') Some samples which they classify as exemplification appear in

English translation as candidates for the part-whole relation (top knot: '...of a quail.' wing: '...any kind of a bird has wings.') The kind of attribution which they call distinctive marker also seems to utilize the part-whole relation. This procedure of naming a whole by one of its parts is not, of course, restricted to Papago - it may be a language universal.

Collins and Quillian (1972) use the name part for the nose-face relation, and they distinguish this relation from the location relation which they call proximity or adjacency. Riegel lists both part and whole as infralogical relations.

While Apresyan, Mel'čuk, and Žolkovsky (1970) do not have a general part-whole relation, several of their relations seem to express specific aspects of the part-whole notion. Cap gives the name of the head of an organization: Cap(tribe) = chief, Cap(regiment) = colonel. Centr relates a concept and its central or culminating part: Centr(life) = prime, Centr(crisis) = peak. The relation Sing is used to carve a countable chunk out of a mass: Sing(news) = item, Sing(violence) = act. Jespersen (1933:206-212) was apparently fascinated by this process, which he called individualization, for he collected many English examples.

In English the part-whole relation seems to be expressed most often with *have*, *of*, or the possessive. Raphael (1968) discriminates between two kinds of *have*, which he calls have-as-parts and own. Simmons (1973) splits *have* three ways:

HASPART	Mary has long fingers	(inverse:PARTOF)
ASSOC	Mary has fun in the park	(inverse:ASSOC)
POSSESS	Mary has money	(inverse:OWNED)

Hendrix (1975) uses a subpart-superpart relation in the semantic component of the Speech Understanding System being developed at the Stanford Research Institute.

Werner and Topper (1976) handle part-whole as a complex relation. 'A thumb is part of the hand', can be diagrammed as in Figure 32 which indicates that a thumb is a hand-part.

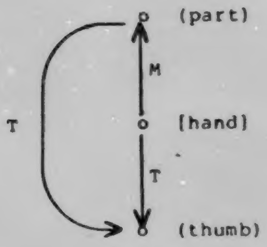

Fig. 32. Part-Whole Relation in Werner's Model.

In the philosophical literature, on the other hand, the part-whole relation has been taken as a primitive. Lesniewski was the first to present a modern axiomatic treatment in his calculus of individuals (Martin 1971). This treatment was somewhat simplified by Tarski (1937). In *Axiomatic Method in Biology* (1937), Woodger includes a 'part-of' relation P, which includes both spatial and temporal parts. He uses this relation to develop a theory of cells and cell-parts. He also discusses its interaction with the relation T, 'before in time'. Martin (1971) sketches a first-order calculus of individuals which includes some axioms for a part relation.

Lyons (1977), Miller and Johnson-Laird (1976), Lehrer (1974b) have all been interested in the part-whole relation and discuss the difficulties in characterizing it. Cruse (1979), in his discussion of the transitivity of the part-whole relation, emphasizes the role of 'functional domain' in determining transitivity. *Finger*, for example, has *hand* as a unique functional domain and is therefore intransitive, whereas *handle* has *door* as a 'variable domain' and therefore permits transitive inference.

2 CAUSE

We have grouped together here those relations which express the fact that two objects or actions co-occur repeatedly or predictably, whether or not this co-occurrence is seen as necessary. This group of relations seems to be particularly important in defining verbs, e.g. to send, in at least one sense, is to cause to go.

Miller and Johnson-Laird differentiate perceptual Cause from conceptual CAUSE (1976:96-100). These, in turn, are not to be confused with linguistic cause (ibid.:468-72). Although these are different, they are expressible by sets of predicates which must ultimately be related to each other. These authors argue that 'the conceptual system is constantly alert to discover causes ... and that the various lexical, morphological and periphrastic devices English provides to denote causal relations explicitly are merely surface indicators of the conceptual core underlying our understanding of causal relations' (ibid.:472). Certainly languages must differ in at least their linguistic realizations of CAUSE.

Causal relations in linguistic forms are most important for verbs although these authors argue against a separate domain of causative verbs for the following reason:

> Presumably, people have some concept of cause, and a few words - cause, force, make, get - seem to express it directly. But causation and intention are expressed ubiquitously in different semantic fields. So we cannot pretend here to be isolating any simple lexical field and looking for its conceptual foundations. We must work from the concept toward its linguistic expression ... realizing that the linguistic expression is usually implicit, a component of the meaning of verbs in many semantic fields (ibid.:478-9).

Miller and Johnson-Laird consider CAUSE to be one of four 'basic semantic operators available for incorporation into complex verbs' (ibid.:482). (The other three are: HAPPEN, INTEND, and DO.) They provide a detailed exploration of the nature and development of CAUSE.

Casagrande and Hale use the term contingency, 'X is defined with relation to a usual or necessary antecedent or concomitant' (1967:172). They also perceive not a single relation but 'two or more closely related ideas. In one case X is defined in terms of some condition or event which it ordinarily follows.' (*to get angry*: 'when we do not like something we get angry.') 'In the second case, Y is a usual or necessary concomitant.' (*to lightning*: 'When it rains, it lightnings.') Kintsch uses the term consequence; his example is *fire* - *smoke*. He also considers CAUSE an atomic predicate.

Gruber (1965) was one of the first linguists to discuss CAUSE as a lexical relation. Some pairs wich he linked by the CAUSE relation are: kill - die, raise - rise, persuade - intend, convince - believe.

No discussion of cause can leave out the generative semanticists. McCawley (1970) treats CAUSE as a two-place relation predicated of a person and an event. As mentioned in section I.2 he proposes a tree as an underlying semantic representation for 'x kill y' with kill decomposable into CAUSE BECOME NOT ALIVE.

Levi (1974, 1976, 1978), a generative semanticist who has paid particular attention to the lexicon, has worked on nonpredicating adjectives. She has provided striking evidence for the theory that these adjectives are derived by predicate deletion from underlying sentences. She lists seven deletable predicates, CAUSE, HAVE, MAKE, BE, USE, IN, and FOR. CAUSE, among others, can apparently be deleted in both active and passive form. After deletion the resulting noun phrase is multiply ambiguous, but predictably so. For example:

CAUSE	(active participle)	malarial mosquitos
CAUSE	(passive participle)	viral pneumonia

There is some evidence that the same seven predicates are precisely those deletable in labels, signs and advertising slogans (Sadock 1974).

Downing (1977) takes a more pragmatic approach to the formation of compounds. She claims that the semantic relations which hold between the members of the compounds (or 'complex nominals' to use Levi's term) cannot be characterized by such a small, finite list of underlying predicates. Rather she states that the appropriateness of a given relation depends on the use to which it is going to be put. The relations don't have to be predictable but are interpretable, especially ad hoc or nonce forms, from the external context in which the compound is used.

A collection of articles has been published which presents some recent linguistic views on CAUSE, viz. Shibatani (1976).

Simmons' (1973) system contains the relations BECAUSE, BEFORE, and AFTER, but his real focus has been on the relative time relationships.

The computer scientist most interested in cause is Schank (1975b). In fact, causal chains make up the backbone of the scripts with which he is currently attacking story-processing and question-answering. In the restaurant script, the customer's entrance causes the hostess to greet him and take him to a table, which causes him to sit down, which causes the waitress to bring a menu, which causes the customer to order, which causes the waitress to bring his food, which causes him to eat... While this rather Calvinist world-view is somewhat unattractive, Schank's question-answering program is impressive. Colby (1976) also uses complex causal chains.

Apresyan, Mel'čuk, and Žolkovsky have several relations in this group. The relation which they call Caus is very different from other cause relations which we have seen. S_{res} is 'the noun denoting the result of C_0'. S_{res}(*to hunt*)=*bag* (1970:16). Perf, the perfective, is defined as 'an action or process carried through to the limit; its standard expression is the perfective aspect of the verb or the perfect tenses'. Perf (*to study*)=*to have mastered*. Result, the resultative, is 'the state or condition resulting from the completion of a certain action or process' (ibid.:17). Caus(C_0) is defined as 'the verb meaning to act in such a way that C_0 comes into being, to create'. Caus(*crisis*) = *to bring about*.

Maxwell (1974) identifies two separate relations, a causal relation, expressed in 'fire causes heat', and a dependency relation, expressed 'flowers need sun'. (See also Smith and Maxwell 1973.)

Werner and Topper (1976) treat cause as a complex relation, built up from taxonomy, modification, and the lexical item *cause*, e.g., the fact that a causes b is represented as 'a is a (kind of) b cause' or (a)T(cause)M[b].

3 SPACE AND LOCATION

There is a close link between relations expressing spatial and locative notions and the part-whole relation. Cruse (1979) reiterates this connection in showing that the functional domain or specific context is significant for acceptability of part-whole statements. To know that one can say, 'an arm has a hand / a hand is part of the arm' and 'a hand has fingers / fingers are part of the hand' but not *'an arm has fingers / fingers are part of the arm', is to know how arm, hand and fingers are spatially (or locatively) attached to one another.

Casagrande and Hale's (1967) constituent, spatial and provenience relations also seem semantically close. This may only be a reflection of the fact that Papago and English carve up space differently. Pinxten (1975) has done a cross cultural study of spatial terms. The S_{loc} relation of Apresyan, Mel'čuk and Žolkovsky (1970) seems to fall somewhere between Casagrande and Hale's spatial relation, provenience and attributive-habitat. S_{loc} (*arrow*) = *quiver*; S_{loc} (*action*) = *scene*. Maxwell (1974) includes a 'locational' relation: 'Heaven is in the sky'. This relation also appears in many of Levi's (1976) adjectives, e.g. marginal note. For Simmons (1973), location is a case relation, LOC. For Riegel (1970), location is an infra-logical relation. Collins and Quillian's (1972) proximity or adjacency relation has already been mentioned in connection with part-whole.

Many authors have attempted typologies of spatial terms according to a componential analysis of the prepositions involved. What the relevant components are vary from author to author. Lyons (1977) distinguishes dimensions such as axes, shape, edges, corners, and orientations. Leech (1969) and Leech and Svartvik (1975) use a cover term 'place' for all spatial locatives which are divided according to point in space, line, surface, area, and volume. Other relevant criteria for further classification include: whether a particular proposition marks dynamic motion (e.g. toward, to, from) or static positions (e.g. at, on, in); directionality, passage, orientation, and distance. Miller and Johnson-Laird (1976:375-410) discuss these distinctions, relating them to interesting developmental and other psychological experimental literature. These authors point out that 'semantic analysis of spatial locatives is complicated by strong interdependencies between the preposition and the relatum' (ibid.:380). In addition, they emphasize the deictic and intrinsic aspects of spatial reference which Fillmore (1975[1971]) has also discussed under the distinction of gestural, anaphoric, and symbolic uses of prepositions of location.

Werner expresses space and location by use of prepositions. In his model this is the one apparent exception to his generally deeper semantic relations. He makes no attempt to decompose prepositions, however, into more elemental units or components as have those above who use componential systems.

Perhaps because spatial locatives are so intralingually and interlinguistically variable, most theorists have not attempted complete expositions of this complex area.

4 PROVENIENCE OR SOURCE

For some relations the perceived structure seems to be strongly influenced by the structure of the language in which the data is gathered. The relation which Casagrande and Hale (1967) call provenience (Milk: '...we get it from a cow.' tray or batea: '...which is made out of mesquite') is expressed in their Papago sample by the elative expression ?amjid. Riegel's (1970) substance relation (table - wood) covers the tray example but not the definition of milk.

Riegel's subjects were speaking English in which the relation between a thing and its source is usually expressed differently for manufactured articles than for naturally occurring ones. Two separate relations seem to provide a more convenient description for English data, since we say that milk comes from a cow, but that a table is made out of wood. Evens and Smith (1978) propose the relations COMESFROM and MADEOUTOF to describe these two aspects of provenience. In their system *milk* COMESFROM *cow* and *table* MADEOUTOF *wood*.

5 ADDITIONAL RELATIONS OF APRESYAN, MEL'ČUK AND ŽOLKOVSKY

Apresyan, Mel'čuk and Žolkovsky's (1970) lexical relations include many which are mentioned seldom, if ever, by other writers. For example, the relation Mult which denotes the totality or aggregate is clearly as important in English as in Russian: Mult(*flowers*) = *bunch*, Mult(*sheep*) = *flock*. Evens found this relation while collecting oral definitions of *book*: 'a book is a collection of pages' (1975:341); 'a book is a series of sheets of paper' (ibid.:339). This relation seems to be a source of productive word play in Russian as in Englsh (e.g. a shrivel of critics, a bevy of beauties, a gaggle of geese).

Their loc relates nouns and their preferred prepositions. loc(*list*) = *on*. Simmons' (1973) PREP also relates prepostions and nouns. The trio of relations Incep, Cont, and Fin express the initiation, continuation, and cessation of action. Maxwell's (1974) inchoative relation seems to function like Incep. The Soviets' S_{instr}, S_{instr}(*to think*) = *brain*, seems to be the relation which Casagrande and Hale (1967) call function:

> *tongue*: 'with which we speak.'
>
> *shovel*: 'with which earth is scooped up.'

Maxwell (1974) calls this relation functional; one example is 'chairs are for sitting'.

Both the source relations and the locative and instrumental-functional relations are closely connected to case relations. They express a kind of typical or characteristic filler for the case slot. The typical source of *milk* is *cow*; the typical location of *arrows* is *quiver*; the typical instrument of *thought* is *brain*. Because of the close connection between these relations and case relations, we will postpone further discussion of them to another occasion. The notions of typicality and collocation also enter here. Many of the relations of Apresyan, Mel'čuk, and Žolkovsky seem to express collocation very explicitly. This problem will be discussed further in section IV.1, but a detailed description of particular collocation relations must also be postponed

One reason why some of these relations, cause and result, in particular, arouse so much controversy is that they play a central part both on the level of the individual lexical item and on the level of events, sentences, and texts. This leads us to a discussion of text relations.

6 TEXT RELATIONS

Models using only text relations attempt to account for the human ability to compose and understand texts. They presume that the basic unit of linguistic structure is the text.

The first attempts to represent the structure of an entire text in relational terms were made by computer scientists. Tharp (1969) devised a logical map for stories from the Childcraft Encyclopedia, in which phrases are connected by surface conjunctions and conjunctive adverbs such as and, because, after, and then. He expressed each passage as a graph using nouns as nodes and noncopula verbs as relational operators between them. Simmons and Slocum (1972) generated paragraphs from a relational network using cases, surface conjunctions, and adverbs as relations. Goldman (1975) combined Simmons' techniques with Schank's (1973) network structure in a more extensive generation model. Taylor (1974) incorporated Simmons' program in an automatic abstracting scheme which attaches weights to each relation and uses signal transmission techniques to prune the network. The relations used in these models, like those we have already examined connect concepts, words, and phrases.

More, recently, Halliday and Hasan (1976) have constructed a model which uses underlying semantic relations to describe the rhetorical structure of a text and express relationships among the words and sentences in that text. In their system a pair of cohesively related words is related by a tie. A tie exists, i.e., two elements in a text are semantically related, when the interpretation of one of the elements in the text is dependent on another in the same text. A cohesive text can then be characterized by the kinds and number of ties present. Halliday and Hasan work with five major types of ties: reference, substitution, ellipsis, conjunction, and lexical cohesion. The categories of devices for realizing these semantic ties textually are given in Figure 33. Halliday and Hasan specifically mention superordinates and synonyms but also allow for many other relations between words (e.g. part-whole, antonymy, etc.) under their category of lexical cohesion. As Halliday and Hasan phrase it (1976:285): 'there is cohesion between any pair of lexical items that stand to each other in some recognizable lexico-senantic...relation'.

Category	Examples
1. Reference	
Personal Pronouns	he, she, them
Demonstratives	this, that, there
Comparatives	biggest, more beautiful
2. Substitution	
Nominal	one, ones, same
Verbal	do
Clausal	so, not
3. Ellipsis	[deletion]
4. Conjunction	
Additive	and
Adversative	yet
Causal	so
Temporal	then
5. Lexical Cohesion	
Generic Nouns	thing, place, men
Superordinates	animal - dog
Synonyms	oculist - eye doctor
Others	mountain - peak

Fig. 33. Categories of Cohesion from Halliday and Hasan.

Eiler (1979), working with Halliday and Hasan, has developed a collection of more specific relations which appear in expository writing about literature. Using these relations she has performed a detailed analysis of texts written by ninth graders.

While Halliday and Hasan have analyzed literary texts using their notion of cohesion (1971,1976), Joseph Grimes (1975) presents a different view of text structure which evolved out of cross-linguistic and cross-cultural workshops on ways to construct discourses. Although the workshops dealt with oral narratives, Grimes' work also draws on previous work with written texts in such areas as biblical translation, literary criticism, and composition. He attempts to account for the whole of discourse by using both lexical relations and rhetorical predicates. Grimes' lexical predicates follow a generative semanticist approach to linguistic structure with heavy emphasis on Fillmorean cases to describe the relationships that obtain between predicates and arguments. Grimes divides cases into orientation roles (object, source, goal, range, vehicle), process roles (patient, material, result, referent), and an agentive complex (agent, instrument, force). Once predicates are organized according to verbs and the cases they require, then these units are combined into larger discourse units by rhetorical predicates. Rhetorical predicates are subdivided into paratactic, hypotactic, and neutral predicates. They are further subdivided, as in Meyer below (see Figure 34). In addition, Grimes uses the notion of cohesion, along with his concept of 'staging', to express the relationship between new and given information. Cohesion is, then, for Grimes more narrowly defined than for Halliday and Hasan, since his lexical and rhetorical units account for some areas covered by other authors' more comprehensive 'cohesion'.

Meyer (1975), a student of Grimes, also describes the interconnections between the basic ideas and persuasive strategies of the text, in terms of rhetorical predicates. (See Figure 34 for a list of Meyer's rhetorical predicates, 1975.) The relations 'alternative' and 'response' are used to organize the key paragraphs in the passage. 'Response' relates a question to an answer, a remark to a reply, or a problem to a solution. 'Alternative' connects various proposed solutions or replies to each other. Arguments which support these main lines are related in Meyer's graph by relations like 'adversative', 'analogy', and 'evidence'. Meyer has tested these relations on expository prose but not on narrative texts. Although they present some technical difficulties, rhetorical relations seem to be a highly valuable addition to the repertoire. These relations correspond to intuitive categories, but they are not clearly defined and therefore it is not easy to apply them

PARATACTIC RHETORICAL PREDICATES	DESCRIPTION
Alternative	Equal weighted alternative options
Response	Equal weighted Question and Answer, Remark and Reply, or Problem(s) and Solution(s).
HYPOTACTIC RHETORICAL PREDICATES	
Attribution	Describes qualities of a proposition
Equivalent	Restates same information in different way
Specific	Gives more specific information about something that was stated in a general manner
Explanation	Previously stated information is explained in a more abstract manner (for example: relating the information to a general principle) or more concrete manner
Evidence	Evidence through perception of some situation to support some idea
Analogy	Analogy given to support some idea
Manner	Way an event or event complex is performed (examples: slowly, carefully)
Adversative	Relates what did not happen to what did happen
Setting time	Gives time of setting in which information being related occurs (often in narratives)
Setting location	Gives location of setting in which information being related occurs (used particularly in narratives)
Setting trajectory	Gives changing background of location and time that occurs in a narrative when characters travel through various places
Representative Identification	Singles out one element of a group and makes it stand for the group as a whole
Replacement Identification	One thing standing for something else
Constituency Identification	Identifies a part in relation to some whole
NEUTRAL RHETORICAL PREDICATES	
Collection	List of elements related in some unspecified manner
Covariance	Relation often referred to as condition, result, or purpose with one argument serving as the Antecedent and the other as the Consequent result of the antecedent

Fig. 34. Meyer's Rhetorical Predicates
(Reprinted with permission from Meyer 1975: 33-34)

consistently to existing texts.

Besides a structural view of texts which Meyer has incorporated into her theory, Grimes also offers a functional organizational matrix which he calls a 'Thurman Chart'. By means of a Thurman Chart one can analyze discourses and subdivide the parts of a narrative according to how each part functions in relation to the whole text. The categories, which form columns on the chart, are: Events, Participants and Non-events. The participant category is divided into participant (i.e. the 'who' of the text) and identifications (i.e. linguistic reference to participants). Non-events include 'settings', 'background', 'collateral', and 'performative' categories, some of which can be further divided into 'evaluations' and 'explanations'. The same story content could vary in different versions, for example, in how much was given in actual story events or how much was given as background or setting.

These same categories, and others like them, appear in narrative analyses and story grammars. Narrative analyses such as Labov and Waletzky's (1966) characterize texts under categories such as: (1) introductions, (2) abstract, (3) orientations, (4) complications, (5) evaluations, (6) results or resolutions, and optionally (7) coda. Categories (3) and (5) are similar to Grimes' settings or backgrounds; (4) to

Grimes' events. Other narrative analyses follow Propp's (1968[1928]) and Dundes' (1964) categories derived from the analyses of myths and use these to examine, for example, children's spontaneous oral narratives (e.g. Botvin and Sutton-Smith 1977).

Story grammars, on the other hand, have come from three major sources and motivations: (1) computer scientists who are trying to extract information from machine-readable texts; (2) cognitive psychologists who seek the role of text structure for memory functioning in reading comprehension; and (3) anthropologists who want to model story-telling processes used in folk tales. The first group includes Schank(1975c) and Rumelhart (1975). The second group includes Mandler and Johnson (1977), Mandler (1978), Kintsch and Greene (1978), and Stein and Nezworski (1978). Among the interesting work produced by the third group is Colby's (1971) grammar of Eskimo folk tales, Lakoff's (1972[1964]) transformational grammar for fairy tales, and Klein's program to generate examples of that modern American folk tale, the murder mystery (Klein et al. 1973). Still other authors represent a combination of Computer Science and Psychology: for example, Thorndyke (1977) and Frederiksen (1977). This is increasingly common as the new field of cognitive science develops out of similar interdisciplinary efforts.

Schank (1975c) states that a sentence in a text has two roles: imparting meaning and connecting with other sentences to form a larger text. He has constructed a model of episodic memory to encompass both sentences and paragraphs by utilizing the same underlying units which he calls ACT's. ACT's are conceptual dependencies within and between sentences (1975a). Sentences are then combined by means of four types of causal links: result causation, enable causation, initiation causation, and reason causation. With the aid of different types of necessary conditions which allow inferences, Schank's model can generate sentences and paragraphs. Relying heavily on the relation of causality, Schank is able to connect sentences into larger contextual frames and scripts and stories through the use of complex causal chains. Unlike some other theorists who model memory storage, Schank does not believe in a hierarchical memory structure such as hypothesized by many for semantic memory. Rather, Schank sees memory as completely episodic; for the structure of such a memory, the kinds of scripts or stories mentioned above would provide not only the input but also the very structure of memory itself.

Rumelhart (1975) has set up a model of memory for stories which owes much to Transformational Generative Grammar (as does Van Dijk 1972, 1977). Rumelhart sets up two sets of rules: one is syntactic; the other is semantic to interpret the results of generation from the syntactic rules. Through a series of rewrite rules, much like those in the phrase structure component of a Transformational Generative Grammar, Rumelhart rewrites a story into underlying conceptual units and then charts the interrelationships between units. For example, a partial set of syntactic rules for his story grammar would include:

story ——> setting + episode
episode ——> event + reaction
event ——> {episode/change of state/action
/event + event}
reaction ——> internal response + overt response
internal response ——> $\left\{\begin{matrix}\text{emotion}\\\text{desire}\end{matrix}\right\}$
overt response ——> $\left\{\begin{matrix}\text{action}\\\text{attempt}\end{matrix}\right\}$
:
:
etc.

Corresponding semantic relationships which connect syntactically generated propositions are: AND, ALLOW, INITIATE, MOTIVATE, CAUSE, THEN (1975:219-223).

While Mandler (1978) and Mandler and Johnson (1977) use a similar model, their list of connectives between propositions includes only three: AND, THEN, CAUSE. Their goal has been to construct developmental studies of recall for stories, either well-constructed (i.e. conforming to a story grammar) or deviant, and note differences that age of subject or 'scrambling' of material make. Along with their own version of Rumelhart-type rewrite rules, Mandler and Johnson include two transformational rules: delete and reorder. For these authors, the grammar has rules such as:

story ——> setting + event structure
event structure ——> episode + episode + ...
episode ——> beginning CAUSE development
CAUSE ending

These, in turn rewrite into categories such as: reaction, goal/path, attempt, outcome. Studies on story recall and story comprehension seek information on, for example, whether beginnings are better remembered than endings, or reactions more poorly remembered than outcomes.

Stein and Nezworski (1978) also construct story grammars to show components, types of information and causal connections between elements of stories. Their grammar includes:

story ——> setting + episode
setting ——> (introduction of protagonist,
social, physical/temporal
context)
episode ——> initiating event + internal

response + attempt +
consequence + reaction

For them, stories have an ideal sequence of elements (above) and they want to know how subjects, especially children, recall stories which do or do not conform to this ideal structure.

Kintsch (1977) and Kintsch and Greene (1978) are also concerned with well-formed stories and the relationship of well-formedness to remembrance. Kintsch and Greene posit the following rules:

schema → episodes
episodes → exposition + complication + resolution
complication → events

Rather than using Story, these authors use Schema, which Bartlett (1932) defined as the macrostructure of a story or particular kind of text. They see texts held together by causal and temporal links. Stories which are generated by rewrite rules of this type create tree diagrams much like Transformational Generative Grammar sentence structure tree diagrams. These authors, and others, feel that superordinate nodes on such a story tree diagram are better remembered than lower-order nodes, and an increase in the amount of embedding under one node can cause increased memory demands. Kintsch and Greene also speak of 'high relational density' which is a measure of the amount or number of conceptual relationships that link any statement to other statements in a passage or story. Such high relational density statements are remembered better.

Thorndyke (1975,1977) also views the place in the structure of a story as crucial in determining comprehensibility and recall, rather than specific content. He also sees higher level elements as remembered better than lower level ones. Thorndyke's grammar includes rules such as:

story → setting + theme + plot + resolution
setting → characters + location + time

etc.

These rules develop an astract hierarchy underlying stories which is like a 'frame' or type. Components of that frame are 'slots' which become filled with story-specific information combining to form an individual story, which is only one example or token of the frame (1977:81).

Colby's (1971) work is intermediate between that of Propp and that of Lakoff and Klein. He analyzed North

Alaskan Eskimo folktales somewhat as Propp analyzed Russian folk tales, but he then developed rules that give a much more detailed narrative structure. The categorial component contains both context-free and context-sensitive rules.

George Lakoff (1972[1964]) examined Propp's analyses of Russian fairy tales and developed a transformational generative grammar for this same body of discourse which was sufficiently powerful to generate actual tales.

Klein and his students at Wisconsin (1973) have developed a system which they have used to generate fairy tales based on Propp's rules as well as murder mysteries. The system has three components: a semantic network, a special-purpose programming language for expressing the rules of a story grammer which directs the way in which story events in the network are generated and manipulated, and third, a semantics-to-surface structure generation mechanism which traces through the network and generates sentences in sequence.

Frederiksen views text structure as a reflection of the knowledge structure of the speaker or writer who produced the text (1977:57). The connection between that knowledge and memory is stated as follows: 'if a semantic distinction or structure is manifest in language, it must also represent an aspect of human memory structure' (ibid.:57). His model of memory structure consists of two networks: (1) a semantic network of labeled binary relations (mostly events or states) which connect (mostly) concepts; and (2) a logical structural network of labeled binary logical, causal, or algebraic relations which connect propositions stated in terms of network one. Frederiksen proposes computer simulation models of decision processes used in processing or producing discourse. He has been concerned with processes involved in text-based inference-making abilities.

A major question in discussing all these authors who are working on text structure is whether they are indeed engaged in semantic analysis and, if so, whether they are using semantic or lexical relations. Most story or text grammars are modeled on the analogy of the sentence grammars of Transformational Generative Grammar. Rather than dealing with grammatical classes of words, however, story grammars deal with conceptual or text-functional classes of elements (e.g. episodes, events, rather than noun phrases, verb phrases). Relations are left in both cases to the inherent structure and organization of the grammatical rules, with sequential order being the major consideration. That which is either overtly (e.g. Rumelhart 1975) or covertly (e.g. Mandler 1978; Kintsch and Greene 1978) termed 'semantic' is confined to CAUSE, THEN, or AND, which link grammatical structures. Elements such as these are in fact called relations by some authors whom we have reviewed earlier (e.g. Rumelhart, Riegel, Levi, Werner, Schank, and Simmons).

None of the text or story grammars appear to be as semantic in nature as Halliday and Hasan's work on cohesive textual ties; and of these ties, the most semantic is their concept of lexical cohesion or collocation. As we have seen the collocation of lexical items, either immediately or at some distance within a text, is a major concern for many theorists. It is to this issue that we now turn.

CHAPTER 4

LEXICAL-SEMANTIC RELATIONS
AND
THE FORM OF THE LEXICON

Two recurring themes which have cropped up in our investigation of lexical relations are relevant to a model of the lexicon and shed light on the nature of lexical-semantic relations. These two themes are lexical collocation and derivation.

Lexical collocation and derivation play a far more important part in the relational systems we have examined than had been expected. This is especially true for the systems posited by the Soviets. The Soviets classify all their lexical functions into two categories, in their terms, two kinds of 'semantic parameters': collocation, and 'replacements' or derivation (Žolkovsky and Mel'čuk 1970:191). Many relations of other authors also implicitly involve either lexical collocations or derived forms. In fact, most relations seem to be classifiable into the dichotomous categories of syntagmatic and paradigmatic, paralleling collocation and derivation. Syntagmatic relations, as discussed earlier, treat lexical items that are frequently or constantly contiguous. Paradigmatic relations have been used in linguistics to describe derivational processes since at least the time of Saussure. These two aspects of lexical relations have been constant sources of controversy throughout the history of linguistics. Different linguistic theories propose radically different models of the lexicon and these require radically different lexical-semantic relations to hold between their entries. The purpose of this chapter then will be to examine the interrelationship between models of the lexicon and the lexical-semantic relations they posit or presuppose.

1 LEXICAL COLLOCATION

The study of lexical collocation, repeated co-occurrence of words in consistent patterns, has long been an especially fruitful field. Lexical collocation has been a cornerstone of British Firthian linguistics. It led to the concept of 'valence' in Soviet machine translation during the 1950's and 1960's. It also led to many studies by American structuralists working in the paradigm of the mathematical theory of communication (cf. Smith 1973 for a survey and criticism of these models). It is now enjoying a revival in such works as Damerau (1971) and Becker (1975), as well as Halliday and Hasan (1976), who analyze all of discourse in terms of its cohesion, basing their analyses in large part on lexical collocation. Collocational relations are one aspect of cohesion, which play an important role in some of the proposals for lexical relations surveyed in this paper.

Apresyan, Mel'čuk and Žolkovsky classify the majority of their relations as functions of lexical collocation or semantic parameters. Semantic parameters, they explain, are:

> ..those lexical functions of which the values are idiomatic expressions, attached to a keyword, of some meanings of a general nature associated with the meaning of that word. This means that in the depth structure the parameter-correlate [value of the function] is used together with the keyword as a separate lexical unit, the choice of the linguistic structure of which is determined by the keyword (1970:191).

These lexical functions include Real (e.g., Real(*promise*) = *to keep*), Incep (e.g., Incep(*war*) = *to break out*), Liqu (e.g., Liqu(*sleep*) = *to disturb*). Plus, Minus, Copul, Cont, Fin, Perf, Fact, Prepar, Degrad, and perhaps Loc. (See Table II for examples.) Four others of their functions may or may not be classifiable as collocational; these are Labor_{ij}, Func_i, Oper_i, and S_i, e.g., Oper_1 (*support*) = *to lend*, Func_2 (*anxiety*) = *to gnaw*.

Some of Apresyan, Mel'čuk, and Žolkovsky's (1970) semantic parameters correlate to deep case relations: S_{mod}, S_{loc}, and S_{res}. Looked at from the point of view of case grammar, they link the keyword to the typical filler of that case slot. Their syntactic theory is based on grammat relations and, not surprisingly, they have a more complete set of lexical relations pointing to typical fillers of various valences or grammatical relation slots. A system of lexical relations based completely on a case grammar must presumably contain a lexical relation corresponding to each case relation (cf. Simmons 1973; Evens 1975). Syntagmatic relations which appear in the study of word associations often fall in the collocational category. Thus many of these relations appear in Riegel's (1970) work, e.g. coordination (*table-chair*) and substance (*table-wood*). In examining word association data Casagrande and Hale (1967) identified coordinate pairs, e.g. *needle and thread*, *bread and butter*, and sequential responses such as *wish bone* and *whistle stop*.

Becker (1975) can serve as a good example of the kinds of assumptions that are made concerning human language by workers in discourse or text analysis. Becker's basic premise is that 'we speak mostly by stitching together swatches of text that we have heard before; productive processes have the secondary role of adapting the old phrases to the new situations' (1975:60). He makes the even stronger claim that 'the wonderful feats of the human intellect...are based as much on memorization as on any impromptu problem-solving' (ibid.:62). Becker claims that the process of speaking is compositional. We start with the information we want to convey and our attitude toward it. Next we draw patterns out of our 'phrasal lexicon' which provide us with the appropriate expression. Then we just stitch the phrases together.

Becker proposes six major categories of lexical phrases:

1. Polywords: multi-word phrases admitting no variability, interchangeable with single words or concepts; they function as single words, e.g., '*to blow up*' = '*to explode*'.
2. Phrasal constraints: units consisting of a small number of words some of which constrain the variability of others; often specify how an expressive function is to be applied. e.g. 'by *pure* coincidence' or 'by *sheer* coincidence'.
3. Deictic locutions: phrases with low variability, short-to-medium length; they serve as clauses or whole utterances whose purpose is to direct the course of conversation, e.g. 'for that matter' (= 'I just thought of a better way of making my point.')
4. Sentence builders: phrases up to sentence length, often containing slots for arguments, e.g., 'A gave B a song and dance about C'.
5. Situational utterances: usually complete sentences, little variability, e.g., 'How can I ever repay you?'
6. Verbatim texts: texts of any length memorized verbatim, or approximately so, e.g., 'Better late than never.'

There are obvious similarities among the categories and it would probably be difficult to agree on the classification of some items, but this taxonomy is of interest. In Becker's view the lexicon must be very large but the number of generalizations to be made from it is comparatively small.

As we have seen, Levi (1976) has proposed a solution for the generation of nominal compounds like birthday cake and piggy bank. Analyses corresponding to Levi's generation scheme would in some cases involve a potential twelve-way ambiguity. She sees no need to have lexical entries for these compounds since they can be generated effectively following her rules. Becker argues: 'You may say that these patterns are implied in the lexical entries for the individual words plus the grammar of English but I say that I am also familiar with the patterns themselves' (1975:63). Charniak (1972) and Evens (1975) have lexical entries for some compounds like piggy bank and birthday cake. They argue for including these compounds as entries because they have found that to interpret even children's stories some specialized knowledge about the compound is needed, which cannot be computed from the entries of the constituents, and the lexical entry for the compound is a convenient place to store it.

These opposing points of view emanate from different theoretical paradigms. Levi is a generative semanticist, while the others are computer scientists. They have different goals: Levi is constructing a parsimonious lexicon; Becker is synthesizing text; Charniak and Evens are analyzing stories. Analysis and synthesis make different demands on a memory model.

Controversy over the nature of the lexicon revolves around basic differences in the assumptions about how much should be stable storage and how much should be process. Researchers, like Becker, who argue for large storage generally do so because they are concerned with including in the storage all necessary information for processing. They also differentiate between processes of analysis and processes of synthesis. Others, like Levi, argue for a parsimonious lexicon accompanied by a complex set of rules which constitute a native speaker's competence. They have little interest in language processing since they consider processing to be a product of performance factors and therefore not of theoretical relevance to the organization of the lexicon. It may be that a truly successful performance model must contain both a phrasal lexicon to account for the speed with which human beings produce familiar phrases and also Levi's rules to explain the human ability to interpret and generate unfamiliar phrases.

2 DERIVATION

The differences between underlying models of the lexicon become even more apparent when we look at the lexical-semantic relations which reflect processes of derivation.

The relations which can be classified as derivational or paradigmatic in the work of Apresyan, Mel'čuk and Žolkovsky (1970) are termed 'replacement correlates'. These can be substituted for the keyword in paraphrases (providing appropriate grammatical transformations have been performed). Examples include S_1 (similar to Simmons' 1973 NP), A_0, Adv_0, V_0, and probably Imper (see Table II for examples). Some of these 'replacement' functions are similar to certain ideas from generative semantics since they point to lexical items which can be decomposed into semantic predicates. For example, $Able_1$ (*to burn*) = *combustible*; $Able_1$ (*to occur*) = *potential*; $Able_2$ (*to read*) = *readable*, *legible*. As in this last example, Apresyan, Mel'čuk, and Žolkovsky never make any distinction between replacements which can be obtained by productive derivational processes and those which are etymologically distant or unrelated.

Among the more interesting recent works in theoretical linguistics which deal with derivational processes have been Zimmer (1964), Botha (1968, 1974), Halle (1973), Matthew (1974), Jackendoff (1975), Lightner (1975) and Aronof (1976).

Derivation is considered an open field of inquiry because of the difficulty in separating key issues. For example, Zimmer asserts that 'processes of word formation often seem to belong to a somewhat vague intermediary area between grammar and lexicon' (1964:18). Matthews, on productive derivation, says, 'the boundary between ordinary and partial productivity is delicate and crucial' (1974:193). Among these works the most controversial has been Halle (1973). He proposes a method for accounting for word formation within the framework of the interpretive semantics of Chomsky's Transformational Grammar. Halle's (1973) morphology contains three components:

1. a list of morphemes,
2. rules of word formation, and
3. an exception filter containing the idiosyncratic properties of words.

There is also a separate dictionary of words (1973:10).

The word formation rules that determine which affixes combine with which stems and in what order produce the potential words in the language. Some lexical entries however behave idiosyncratically with respect to their resultant meaning. For example, recital refers to a performance of music by a soloist and not to the recitation of poetry or to the performance of a full orchestra. Similarly, the word approbation has a related word approval but derivation does not have the potential related form *derival. Halle (ibid.:3) proposes that such idiosyncrasies of lexical items be listed in an exception filter through which all words are passed after they have been generated by the rules of word formation. The information given in the filter under each entry is then added to the representation of the word in the dictionary, e.g., the information that recital only refers to solo music performance. Lexical gaps such as derival have the feature [-Lexical Insertion] appended to them. All potential but nonoccurring words in the language are thus listed in the filter. Botha's (1974) refinement to Halle's proposal is to make the filter a surface filter.

The problem with both these proposals is that exactly those word formation processes which are needed to account for the creation and understanding of new words can produce lists of exceptional words of potentially infinite length. To cite one of Halle's own examples (1973:12-13), the process of diminutive formation in Russian by which the suffix -ok can be added to a noun in order to form a diminutive can be applied recursively. The recursive application of this rule can easily produce an infinite number of such diminutives from one noun stem. The fact that this does not occur is a problem which has led linguists to invent readjustment rules and global constraints to limit the application of rules.

Jackendoff's (1975) approach to the problem of word formation, based on Chomsky (1970), and proposed independently from Halle, involves the use of morphological and semantic redundancy rules. There are lexical entries for all full words and only those. No filter is required. Words in the lexicon are related via redundancy rules. For example, the words decide and decision are related by the symmetric relation 'is lexically related to' where one of the words is taken as basic and the other is derived from it. Jackendoff does not emphasize the direction of derivation which is so important in traditional discussions of derivational morphology. The notion of lexical relation plays a much more important role than derivation for Jackendoff. Though some posit an underlying (but non-surface-occurring) verb aggress for the set aggression-aggressor-aggressive, Jackendoff disallows this since it is not a full word. Instead he states, 'the choice of one of the three as basic must be purely arbitrary' (1975:648). Instead of listing aggress as an entry in the lexicon, it is mentioned as information under the full entries for the words that are lexically related to it along with the redundancy rules which apply to generate the surface forms. As Jackendoff states: 'The full-entry theory provides a description of rootless pairs and triplets which avoids either a root in the lexicon or a claim that one member of the group is basic...the lexicon is simply a repository of all information about all the existing words' (ibid.:649). A feature such as [-Lexical Insertion] also does not appear on any entry since only actually occurring words are listed in the lexicon. Productive derivational processes are handled via the redundancy rules, although it is not completely clear to us how this is to be done. Redundancy rules are stated so generally that prefixes and stems listed in a redundancy rule allow for new combinations. Once this is done, the lexicon is consequently restructured.

In a similar study Aronoff recognizes the fact that a speaker's word list is not closed and that one has the capacity to make up new words (1976:19). Words are formed from other words (so-called bases) with no abstract stages (ibid.:57). They are entered in the lexicon in a fully concrete, specified form (ibid.:46). All productive word-formation processes are word-based. A new word is formed by applying a regular rule to a single already existing word. This is somewhat similar to Jackendoff's proposal.

With Chomsky (1965) and others, Aronoff assumes that only exceptional forms are listed in the lexicon. Productive formations, that is, those that are semantically coherent (with a meaning that can be predicted from the Word Formation Rule), are not listed (1976:43-44). There is an apparent contradiction between this statement and an earlier one however: 'I do not view these rules as applying every time the speaker of a language speaks. They are rules for making up new words which may be added to the speaker's lexicon. We can think of them as once-only rules' (ibid.:22). Old words are idiosyncratic; only new words are created with the help of rules. There are no lexical gaps in Aronoff's system since gaps presuppose a list and there is no list (ibid.:45).

In Aronoff Word Formation Rules are rules of the lexicon and operate totally within it. As such they may only refer to syntactic, semantic, and phonological properties of words within the lexicon and not to rules for the rest of the grammar (ibid.:46). These Word Formation Rules consist of three parts - the base, the operation, and the conditions - and operate only on words of the four major lexical categories, that is, on nouns, verbs, adjectives, and adverbs.

In Generative Semantics the notion of 'possible lexical item', and therefore the notion of gaps, is explained by stating that only lexical items which correspond to syntactic constituents can exist in a particular language. These arise from well-formed semantic representations via prelexical transformations. Gaps are entries which have not received phonological labels.

The position of Montague grammarians on the problem of derivation is discussed in part in Dowty (1975, 1976). One of the basic tenets of this theory is that there is no distinction between lexical and nonlexical categories. Any category can potentially have lexical items as its members (called 'basic expressions' of the category) as well as complex phrases formed by means of syntactic rules.

In Montague grammar the purpose of word-formation rules is to increase the stock of basic expressions in the language (lexical entries). As in Aronoff (1976) these rules are not considered a part of the grammar of the language proper but as 'a means for modifying the grammar by enlarging its lexicon' (Dowty 1976:237).

Dowty agrees with Jackendoff and Aronoff that full entries are stored in the lexicon so that word-formation rules combine or transform basic expressions into other basic expressions just as syntactic rules combine or transform phrases to produce other phrases.

What these theories of derivational processes have to say about the form of the lexicon is that lexical relations must be marked in the lexicon. What has not become apparent until this comparative analysis is how rich and varied the system of lexical relations will really have to be in any model of the lexicon.

The problems of collocation and derivation affect the nature of systems of lexical-semantic relations. Each discipline attacks these problems differently. Within disciplines, models of competence differ in demands on the lexicon from models of performance, which may themselves emphasize either analysis or synthesis. Linguistic paradigms, such as case grammar or generative semantics, involve strong hypotheses about relations. A complete system of relations must account for both collocational and derivational processes, for both paradigmatic and syntagmatic aspects of language.

CHAPTER 5

CONCLUSIONS

An obvious question raised by this comparative study of lexical semantic relations is: why is there such a disparity among the various authors in the number and type of relations they posit? It can be safely assumed that each author tries to account for as much as possible. If this means that the lists are as complete as each author thinks necessary, why then are there such disparate inventories? The answer lies in the paradigm that each author adopts.

To examine this question more closely let us look at the extremes of the continuum of systems of lexical relations. Apresyan, Mel'čuk and Žolkovsky propose almost fifty relations while Werner operates with only three.

Werner is a reductionist, who is trying to limit the theoretical machinery needed to account for a person's cultural knowledge. A major motivation for this reductionist tendency is that the identification of a small set of universal relations facilitates the analysis of an unfamiliar system of concepts. Werner's and Casagrande and

Hale's data are predominantly texts and folk definitions elicited in field work with native informants. Their interest is to establish relations primarily on the conceptual level of information processing. By contrast, Apresyan, Mel'čuk, and Žolkovsky have set out to perform a very different task. Their goal is the construction of a dictionary of Russian which will allow for the synthesis of contemporary standard Russian text from some underlying logico-semantic Basic Russian. Their rules are intended to generate all possible paraphrases of any Russian sentence. This requires detailed language-particular syntactic and morphological information as well as abstract linguistic universals. This explains, at least in part, the disparity between Apresyan, Mel'čuk, and Žolkovsky and these anthropologists.

In reviewing the many workers who are distributed along this continuum between Apresyan, Mel'čuk, and Žolkovsky and Werner it seems that the field, school of thought, and individual predilection determine the choice of a paradigm. The paradigm in turn determines the choice of relevant data, goal, and model, as shown in Figure 35.

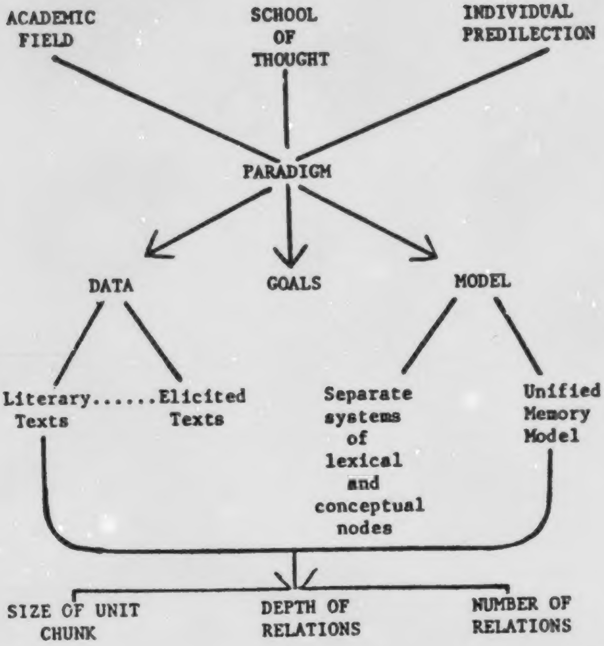
ACADEMIC FIELD
SCHOOL OF THOUGHT
INDIVIDUAL PREDILECTION
PARADIGM
DATA
GOALS
MODEL
Literary Texts
......
Elicited Texts
Separate systems of lexical and conceptual nodes
Unified Memory Model
SIZE OF UNIT CHUNK
DEPTH OF RELATIONS
NUMBER OF RELATIONS

Fig. 35. Some Factors Determining the Choice of a Relational Model.

Depending upon a particular paradigm, sets of questions do or do not arise. For example, the nature of memory is crucial for psychologists but not for generative semanticists. However, both psychologists and linguists are concerned with other common interests such as fuzzy sets. Computer scientists, for their part, share some interests with psychologists (e.g. memory structure) and some with linguists (e.g. constraints on language production).

Furthermore, within a single field there can be several different paradigms correlated to opposing stands on critical issues. For example, in linguistics the issue of the nature of the lexicon divides Transformational Generative Grammarians from Generative Semanticists. In computer science, the issue of psychological reality divides workers in artificial intelligence into two camps: on one side are those who are building models of human language processing; on the other are those who are trying to make a program perform a human task, but not necessarily as humans do. The issue of the existence of covert nodes separates researchers in anthropology. For psychologists, their ranks are divided on how much and in what way information is stored and processed in memory.

The instruments available to a researcher may also influence the form of a model. For example, the use of LISP by many computer scientists may have led them to posit attribute lists for modification. Various tests and measuring devices in psychology yield data on hierarchically organized categories which favor super/subordinate or taxonomic relations but not some others. Also, the preference by some linguists for predicate calculus may influence their conception of models of underlying semantics.

Data and goal are themselves intertwined in the development of a relational model. Casagrande and Hale start with a study of dialect variation based on descriptions of cultural objects. Apresyan, Mel'čuk, and Žolkovsky begin with an attempt at automatic paraphrase. Simmons sets out to build models of paragraph generation and question-answering. Riegel wants a theoretical basis for word association responses. Werner aims at a unified memory model, a synthetic informant capable of simulating human responses. Levi's competence model of nominal compounds is radically opposed to Becker's performance model of a phrasal lexicon.

A model chosen by an author will influence the form, nature, and number of lexical-semantic relations proposed. In particular, models which posit a structure for the lexicon and its relation to the rest of memory have had a very strong effect in determining the form of lexical relations. Thus, systems of lexical-semantic relations have been strongly influenced by some linguists who do not explicitly use relations themselves but who have nevertheless contributed to our understanding of the nature of the lexicon.

The decision between an integrated memory model and separate systems of lexical and conceptual nodes seems to have a particularly strong influence on the choice of relations. In Simmons' model, there are separate systems of lexical nodes and conceptual nodes; each has its own set of relations. Clearly Simmons recognizes the distinction between semantic and episodic memory since he posits separate systems. Schank, on the other hand, believes that all memory is episodic and his model reflects that belief. In Werner's unified memory model, nodes at all levels are connected by the same set of relations.

Apparently, data, goal, and model together determine the system of relations, their number, their depth, and the size of the units which they relate, as represented in Figure 36. Authors whose goal is to discover the nature of cultural knowledge (i.e. encyclopedic knowledge), how it is learned, stored, and used, tend to have fewer but deeper semantic relations. These relations are very general, if not universal, and they form the basis for the generation of other relations, which are both derived and closer to the surface. Those authors who account exhaustively for the relations in a particular language are more concerned with lexical connections (i.e. dictionary knowledge), problems of collocation and derivation of lexical items, and thus with distinctions such as between syntagmatic and paradigmatic parameters.

DEPTH OF RELATION	MAJOR CONCERN	NUMBER OF RELATIONS	TYPE OF RELATIONS
Deeper	Conceptual	Fewer	Semantic
Closer to Surface	Lexical Collocation and Derivation	Large Number	Lexical Relations

Fig. 36. Some Possible Relationships.

Linguistic level in the transformational generative grammatical sense also distinguishes between more surface level models like that of Apresyan, Mel'čuk, and Žolkovsky and the deeper models of Simmons and Werner. Linguistic levels can also be used to differentiate the size of the units in these models. The earliest use of relations tended to operate on single concepts and words, but then grew to include sentences and their constituents. Recently the use of relations has expanded to describe the whole rhetorical structure of narrative and expository passages.

There are several important questions which we cannot begin to answer:

(1) Is there really a boundary between lexical and semantic relations? Can one model contain both lexical and semantic relations where semantic relations represent deeper conceptual information and lexical relations represent closer to the surface connections between words which often occur together (e.g. compounds, idioms, typical subjects) or words which are derivationally connected (e.g. conquer - conquest).

(2) Collocational and derivational relations play a much more important part than we had expected. Mel'čuk, Apresyan and Žolkovsky have many relations of this type. Paralleling each grammatical relation in their system is a lexical relation which lists the typical filler of the grammatical slot, e.g. typical subject: conquer - conqueror. Systems which use case relations need to mark typical fillers of case argument slots instead. While for the Soviets, productive derivational forms are extremely important, Casagrande and Hale classify them as uninteresting circular definitions. What then is the place of collocation and derivation in a complete model of language?

(3) What is the relationship between concept and

structure? To what extent should researchers in the area of lexical-semantic relations be concerned about concepts? If there is a relationship between semantics and the structure of concepts, how can it be unearthed? Must we first understand the relationships between intension and extension, context and variability, collocations, and other issues that have surfaced in the preceding chapters?

(4) The question of context is of increasing importance to researchers. Through the discussion of lexical collocation we have seen that the immediate context is more crucial than we had anticipated. Recent emphasis on narrative and text structures is evidence that more extended contexts are being viewed as critical for understanding the smaller bits of information embedded in them. Even beyond the text, the situational context of language has become a major focus of sociolinguistic variation, on the one hand, and pragmatics, on the other. Among the authors reviewed here, Werner has seen the need to account for dialect variability in his model; and Schank, Winograd, and Fillmore have attempted to show the interdependency of language and situation through the notion of frames and scripts. In addition, the issues of the difference between semantic and episodic memory as well as the notion of procedural semantics both involve the question of how to deal with context. A major question for future research, then, is: to what degree

and in what way should one account for these different kinds of context in a complete model of lexical/sematic relations?

(5) The problems of semantic primes and circularity of definition also reveal sharp conflicts between scholars working on semantic relations, even between those working in the same discipline. Schank (1973) makes a very strong statement about language universality and semantic primes; indeed he claims to have developed a system for the 'representation of meaning in an unambiguous language-free manner' (ibid.:187) and to have identified a set of semantic primes (ibid.:228) in which to frame this representation.

Wilks, in reporting his experiments on machine translation, describes his ELEMENTS as 'sixty primitive semantic units used to express the semantic entities, states, qualities, and actions about which humans speak and write', and attacks as irresponsible those who add semantic primitives to their systems at will (1973:123-124).

Winograd, also a computer scientist seeking solutions to the same problems of computational linguistics, expresses a completely opposite point of view. Language, he says 'is incomplete, highly redundant, and often inconsistent. There is no self-contained set of "primitives" from which everything else can be defined. Definitions are circular with the meanings of each concept depending on every other concept' (1971:210). Collins and Quillian seem to agree with Winograd: 'There are no primitive or undefined terms in the mathematical sense, everything is defined in terms of everything else so the usual logical structure of mathematical systems does not hold. In this respect, it [memory network] is like a dictionary' (1972:313-4). But not everyone would agree that there are no primitive terms in a dictionary.

Circular definitions are also a center of controversy. Are they inevitable or can they be avoided? Casagrande and Hale classify as circular all definitions which define a word in terms of itself or a regularly formed derivative. They do not find these definitions very interesting, complaining that they do not supply much cultural information. Perhaps such a definition is a valuable pointer to a potential semantic prime. Werner has found in eliciting definitions in Navajo that postpositions (which are equivalent to prepositions in English) are often defined in this fashion.

Apresyan, Mel'čuk, and Žolkovsky disagree with Winograd about circularity and primes: 'Definitions should not be circular...all definitions will in the long run be reduced to a small number of indefinable units of meaning' (1970:4). The psychologist Kintsch states flatly in opposition, 'Talking about semantic relationships between words has two important implications: first, it makes clear that any word may be related to any other word, that is, there is no set of primitive terms; second, a relationship is a complex expression, unlike a feature or marker... We find impractical the notion of a small number of primitive semantic relations' (1972:251). Clearly there is no agreement on the philosophical basis or status of semantic primes.

(6) Another unanswered question about relations is whether they are language universal or language specific. Are relations semantic primitives? Do they have a real existence? Could we have a special version of Zwicky's substance theory for relations? Most of the work which we have described has involved models of English with some important exceptions: Werner has worked extensively with Navajo; Casgrande and Hale collected definitions in Papago; Mel'čuk is now applying to French the theories and methods which he and his co-workers developed originally in Russian. Martin (1975) expresses concern that models are shaped by the structures of English; different languages may give rise to different relations and different primitives in other categories.

(7) Still another question, a very speculative one, is:

Could there be a valid theory of relations of relations? Riegel posits relations of relations, while Werner has been investigating methods of decomposing relations into his three primary MTQ relations. While Mel'čuk finds relational inverses of no particular interest, Raphael, Hendrix, and Evens have all made use of them.

In summary, all the models we have considered posit several relations as important: taxonomy, modification, synonymy, antonymy and grading. There remains some controversy as to whether synonymy and antonymy deserve separate status or whether synonymy is an aspect of taxonomy and antonymy an aspect of grading. The reason why these relations are 'major' can be sought in the comparative descriptions of each relation, in the formal properties of each relation, and in connections to other relations. Several other relations occurred often enough in various models or were of sufficient importance to an author that we examined these as well: part-whole, cause, space and location, provenience or source, and text relations. The recurring problems of collocation and derivation became an issue and raised questions about the nature of the lexicon.

In conclusion, goals and methodologies vary between disciplines. The nature of the proposed relational system of an author depends upon the paradigm in which the work is done so that even within one discipline, several models will be possible. These paradigms, and therefore the models, vary according to the number of relations posited, the depth at which relations operate, and the amount of data which can be considered as a unit. Each model implies in turn a view of language, of memory, and of knowledge.

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